TGT-279

SUPPLEMENT TO JULY 1963 REPORT

The International Passamaquoddy TIDAL POWER PROJECT and UPPER SAINT JOHN RIVER Hydroelectric Power Development

AUGUST 1964

REPORT to

Stewart L. Udall, Secretary
U. S. Department of the Interior

by

Passamaquoddy - Saint John River
Study Committee

This report was prepared in conformance with the Policies, Standards, and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources, Senate Document 97, 87th Congress, which was approved on May 15, 1962 for application of the Departments of the Army; Agriculture; Health, Education and Welfare; and Interior in water resource planning and by the Bureau of the Budget in reviewing proposed programs and projects of the Federal Government.

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

August 3, 1964

MEMORANDUM

To: Secretary of the Interior

From: Passamaquoddy-Saint John River Study Committee

Subject: The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development

We submit herewith the report which supplements the earlier report which was transmitted to President John F. Kennedy on July 1, 1963, entitled "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development." This report was prepared under the supervision of Assistant Secretary Kenneth Holum, Water and Power Development.

Under established Federal financial procedures and criteria, we have found the proposed Passamaquoddy-Dickey Project, Maine and New Brunswick, engineeringly and financially feasible. For the first time in the history of this Nation, it would harness the enormous energy of the ocean's tides for the production of relatively low cost and abundant electricity in the New England area. It would provide immediate and sustained employment opportunities, flood control, recreation, an international tourist attraction, hydroelectric power generation on the Upper Saint John River in Maine and downstream power benefits in Canada.

This report contains the findings from the addtional investigations completed by the Corps of Engineers, U. S. Army, and this Department since President Kennedy's acceptance of the previous report on July 16, 1963. In directing these studies be undertaken, the late President recognized that since the project involves international waters, equitable agreements must be reached with the Canadian Government before its construction could be started. The Department of State was directed to proceed toward accomplishing such agreements. We have been, and will continue, to assist as necessary in this endeavor.

Lt. Gen. W. K. Wilson, Jr., Chief of Engineers, U. S. Army, by letter of July 29, 1963, proposed the establishment of an eight member Army-Interior Advisory Board on the Passamaquoddy and Upper Saint John River Project composed of four representatives from each Agency. The purpose of this Board was to advise and guide both Agencies in the additional work required to supplement the July 1 report. By letter of July 30, 1963, the Department accepted the proposal. Later the Board was augmented to include representatives of the Department of Commerce and the Federal Power Commission as participating members, and representatives of the Bureau of the Budget, the President's Office of Science and Technology, the President's Council of Economic Advisors, and the Atomic Energy Commission, as observers.

The Board contributed immeasurably in both the evaluation and investigation of the project and in perfecting the report. Each of the Agency representatives contributed generously of his talents and time, but have not yet concurred in this report. The results of this joint effort are embodied in this report.

The basic project would be comprised of the Passamaquoddy Tidal Power Development with an initial installation of 500-Mw and an ultimate installation of 1,000 Mw; the Dickey reservoir and powerplant with an installed capacity of 760-Mw; the Lincoln School reregulating reservoir and powerplant with an installed capacity of 34-Mw; and a transmission system interconnecting these plants and delivering power to load centers in Maine and in the vicinity of Boston, Massachusetts. The Passamaquoddy powerplant would utilize the two-pool plan proposed and described in the International Joint Commission's report of April 1961 and all features would be identical with the exception of the powerplants.

In the International Joint Commission plan, an installed capacity of 300-Mw was proposed and the powerplant was to be operated to produce load factor power to serve a local area. In the present proposal, an initial capacity of 500-Mw would be installed and ultimately 1,000-Mw, and the plant would be operated to provide peaking power to supply an expanded marketing area of New England and New Brunswick. The powerplant would incorporate reversible features in the turbines which would enable the generating units to be operated as pumps during the periods of neap tide so that the dependable capacity would be determined by the installed capacities in the powerhouses and not by the magnitude of the neap tide. An insignificant increase in the investment cost and in the cost of energy for pumping would be required to accomplish this improvement.

The Dickey and Lincoln School powerplants on the Upper Saint John River would be electrically interconnected with the Passamaquoddy powerplant and coordinated so as to produce the optimum benefits. The operation would be extremely flexible and considerable quantities of load factor power could be provided for the local areas and, in addition, very substantial quantities of peaking power. In the current analysis, a peak of two hours duration was considered a very likely occurrence and this was selected for the basis of the analysis.

The total power output of the project would be 1,794-Mw as the ultimate installed capacity. However, in the initial plan, only 1,294-Mw is recommended, which can be installed in stages to meet the load demands. Generation will be provided at-site of about 3 billion kilowatthours and downstream benefits in Canada of 656 million kilowatthours, annually. The cost of the project is approximately $896 million, including a transmission system at a cost of $87 million. This investment would provide annual benefits of $46.86 million, of which $42.51 million would be power, $2.03 million recreation, $2.28 million area redevelopment and $0.04 million flood control benefits within the United States, with significant flood control benefits to Canada which have not been evaluated in the project benefits.

The recommended benefit-cost ratio of the Passamaquoddy-Dickey Project is 1.47 to 1.00, of which the Dickey and Lincoln School benefit-cost ratio is 2.25 to 1.00, and the Passamaquoddy Tidal Power Project's benefit-cost ratio is 1.04 to 1.00. The segments of this project complement each other and together create values which are greater than would be obtained from either operating independently. These benefit-cost ratios were determined for a 100-year period of analysis with interest at 3 percent.

With an allocation of about 10 percent to the non-power features, the investment in the project can be repaid with interest at 3 percent within a 50-year period after each unit becomes revenue producing from revenues from the sale of power at the following rates:

Capacity	$19.75 per Kilowatt-year
Energy	3.0 Mills per kilowatthour

The above prices are lower than power that can be produced by privately financed new modern conventional steam plants, nuclear powerplants using light water reactors, and pumped storage plants with the transmission essential to deliver power to the load centers.

In accordance with the established procedures and criteria for project formulation and evaluation, we have also considered the least costly alternative. If federally financed, conventional steam, nuclear powerplants and pumped storage plants would cost less than the project. However, the proposed development of the Passamaquoddy-Dickey Project will provide more benefits than just power supply. The enormous and perpetual energy of the ocean's tides will be utilized instead of wasted. The construction of this project will provide greatly expanded employment opportunities as well as attractive recreational opportunities for an expanding population, with a resulting impact on the economy of the State of Maine and surrounding areas.

In view of the extensive previous investigations made on the project dating back to 1922 and the additional studies made in connection with the review of the report requested by the late President Kennedy, plus the work accomplished under the advice of the Passamaquoddy Advisory Board, we are firmly convinced that the construction of the Passamaquoddy-Dickey Project as a Federal development will benefit Maine, New England, the Maritime Provinces, Canada, and the United States of America. Agreements, of course, must be reached with the Canadian Government.

We recommend early consideration moving towards possible authorization of the International Passamaquoddy Tidal Power Project and the Upper Saint John River Developments for construction by the Corps of Engineers, U. S. Army, and marketing of power and construction of transmission lines by the Department of the Interior.

As specified in Senate Document 97, 87th Congress, we are transmitting this report to the interested Federal Agencies, the Governors of the New England States, as well as to the appropriate national and provincial representatives of the Dominion of Canada for comment. Such comments as are received will be reviewed and incorporated in your final report to the President of the United States.

Morgan D. Dubrow

Morgan D. Dubrow, Chairman

Joseph E. Guidry

Joseph E. Guidry, Project Engineer

Supplement to July 1963 Report

The International Passamaquoddy Tidal Power Project And Upper Saint John River Hydroelectric Power Development

Report to Stewart L. Udall, Secretary
U. S. Department of the Interior

by
Passamaquoddy - Saint John River Study Committee

August 1964

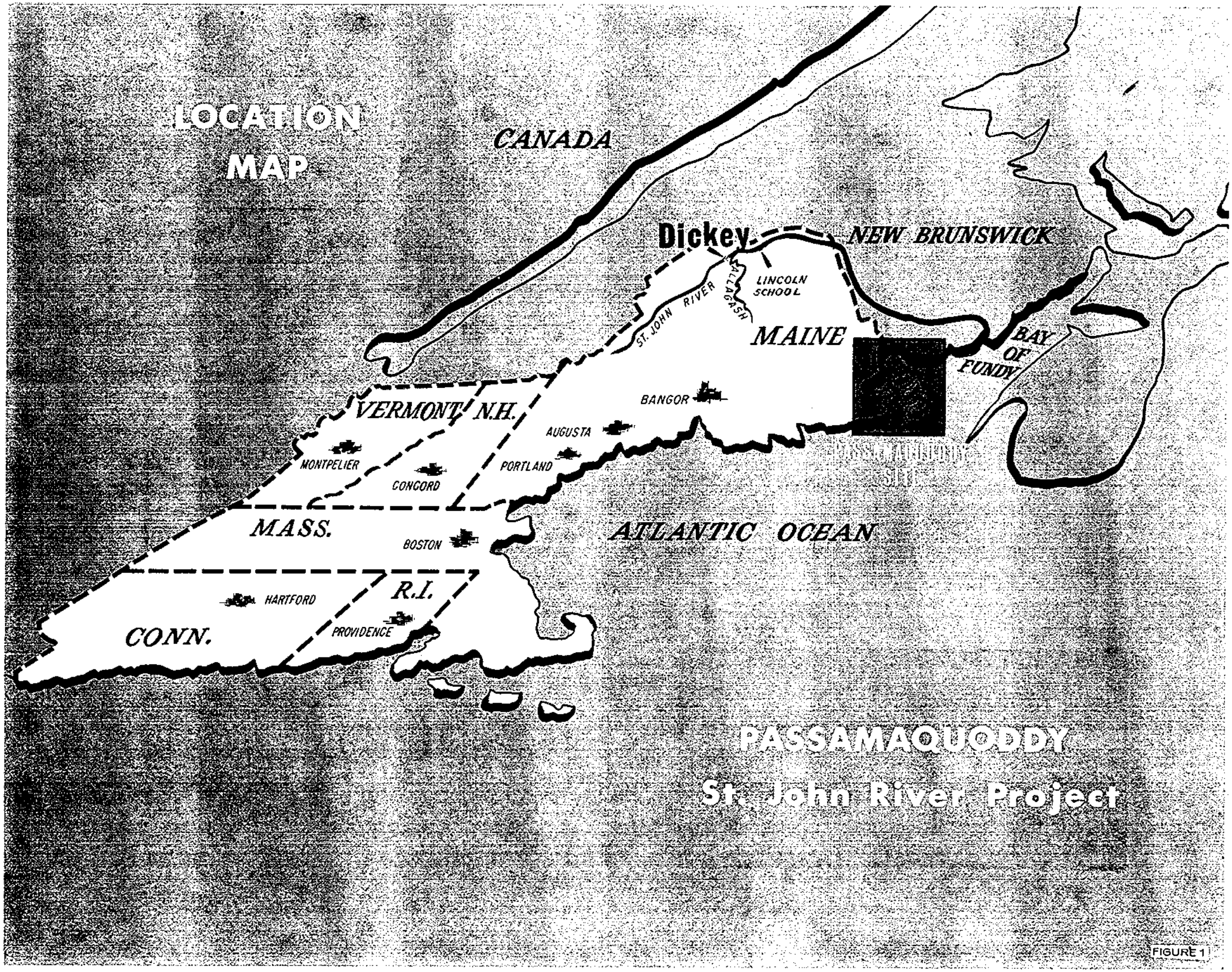
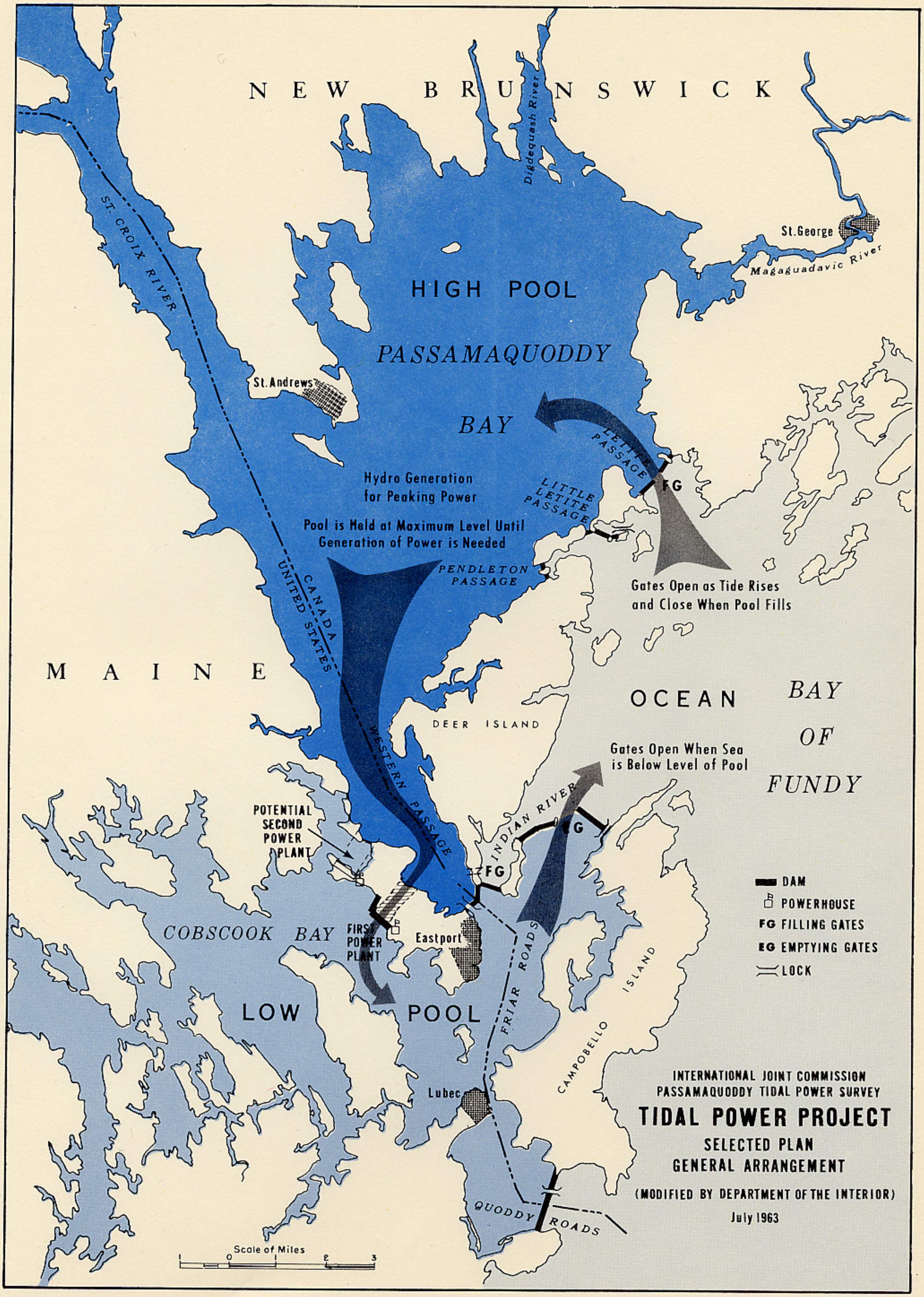

LOCATION MAP
CANADA
Dickey
NEW BRUNSWICK
LINCOLN SCHOOL
ST. JOHN RIVER
ALLAGASH
MAINE
BAY OF FUNDY
BANGOR
AUGUSTA
PORTLAND
VERMONT
N.H.
MONTPELIER
CONCORD
MASS.
BOSTON
ATLANTIC OCEAN
R.I.
HARTFORD
PROVIDENCE
CONN.
PASSAMAQUODDY
St. John River Project

FIGURE 1



NEW BRUNSWICK
Digdeguash River
St.George
Magaguadavic River
ST. CROIX RIVER
HIGH POOL
PASSAMAQUODDY
BAY
St.Andrews
LETITE PASSAGE
FG
LITTLE LETITE PASSAGE
Hydro Generation
for Peaking Power
Pool is Held at Maximum Level Until
Generation of Power is Needed
PENDLETON PASSAGE
Gates Open as Tide Rises
and Close When Pool Fills
CANADA
UNITED STATES
MAINE
OCEAN
BAY
OF
FUNDY
DEER ISLAND
WESTERN PASSAGE
Gates Open When Sea
is Below Level of Pool
INDIAN RIVER
EG
FG
POTENTIAL
SECOND
POWER
PLANT
COBSCOOK BAY
FIRST
POWER
PLANT
Eastport
FRIAR ROADS
ISLAND
DAM
POWERHOUSE
FG FILLING GATES
EG EMPTYING GATES
LOCK
LOW
POOL
CAMPOBELLO
Lubec
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL POWER PROJECT
SELECTED PLAN
GENERAL ARRANGEMENT
(MODIFIED BY DEPARTMENT OF THE INTERIOR)
July 1963
QUODDY
ROADS
Scale of Miles
1 0 1 2 3

Figure 2

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Supplementary Engineering Report, April 1964,
U. S. Army Engineer Division, New England
Corps of Engineers, Waltham, Massachusetts

CHAPTER I

PURPOSE AND SCOPE OF REPORT

The purpose of this report is to present additional conclusions of the Department of the Interior's review of the International Joint Commission's report on the International Passamaquoddy Tidal Power Project, April - 1961. It supplements the report of July 1963 entitled "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development."

The report embraces the considerations and suggestions of the Joint Army-Interior Advisory Board, which was created shortly after President Kennedy's acceptance of the Department's report on July 16, 1963. This Board consists of representatives from the Corps of Engineers, the Department of the Interior, the Department of Commerce and the Federal Power Commission as participating members, with representatives of the Bureau of the Budget, the President's Office of Science and Technology, the President's Council of Economic Advisors and the Atomic Energy Commission as observers.

The suggestions of all representatives on the Board were considered, but since the Board's function was advisory, the views of the individuals might not necessarily fully conform with the Agencies' position in commenting on the report.

The following contributions by the Corps of Engineers are included:

a. Geologic investigations and field explorations at the sites of all structural components.

b. Field Surveys.

c. Hydrologic investigations of the Saint John River.

d. Layout and design of facilities for powerplants at Passamaquoddy; power dam and closure dikes at Dickey; and reregulating and power dam at Lincoln School.

e. Studies of use of inclined axis turbines at Passamaquoddy in cooperation with the Bureau of Reclamation.

f. Planning appraisal of all lands and damages for the entire project.

g. Cost estimates of facilities.

The Department of the Interior in its traditional role for water resource development accepts the basic responsibility for this report which portrays a feasible and workable plan for utilization of this unique water power resource -- the tides. The Department conducted the economic analysis and marketing studies and provided the cost estimates for the transmission facilities.

The Department of State is working towards an agreement with the Canadian Government. A technical briefing session was held in Ottawa, Canada, December 4 - 5, 1963, as well as other meetings between officials of the two countries.

CHAPTER II

SUMMARY - FINDINGS

The results accomplished since completion of the July 1, 1963 report confirm the engineering and economic feasibility and the desirability of constructing, by the United States, the proposed International Passamaquoddy Tidal Power Project, the Dickey storage reservoir and powerplant, and the Lincoln School re-regulating reservoir and powerplant on the Upper Saint John River and the associated transmission system. These include firm geologic data and more detailed economic analyses than previously applied as well as updated cost estimates.

The proposed project offers a practical plan for harnessing, for the first time in the history of this Nation, the energy of the tides for the economic benefit of a large section of the country. The coupling of this resource with development of the hydroelectric power potential of the Upper Saint John River provides a multi-purpose project with very significant electric power, flood control, recreation and area redevelopment benefits. Each of these will constitute a significant element in the area's economy. Wasting of the energy in the tides and in the flows of the Upper Saint John River would be eliminated and changed to economic gain.

A major contribution from the project would be hydroelectric power. The project would provide a large block of peaking and load factor power which can be utilized advantageously in the New England-New Brunswick area. It is in the production of peaking power that the present Passamaquoddy proposal differs from the previous concepts in which an attempt was made to match the tidal power which follows the lunar day of 24 hours and 50 minutes with the electric power pattern which follows our living habits on a solar day of 24 hours.

The installed capacity of the ultimate project would total 1,794-MW. However, the second 500-MW powerplant at Passamaquoddy is deferred for future installation. The initial project would provide 1,294-MW of dependable capacity and approximately 3 billion kilowatthours of electrical energy annually. The two-pool plan envisioned in the International Joint Commission's report for Passamaquoddy would be used with a 500-MW powerplant instead of the 300-MW plant originally contemplated. The powerhouse would be located at Carryingplace Cove, the site originally chosen for the 300-MW plant. The 500-MW plant would be interconnected through a transmission system with two powerplants on the Upper Saint John River, Dickey with 760-MW capacity, and Lincoln School with an installation of 34-MW.

The project could be constructed in stages as the load demands grow. Initial operation of the first powerhouse at the Passamaquoddy Tidal Power Development would require about six years after constructed is started. The second powerhouse at Passamaquoddy would take about five years. Dickey would require three and one-half years and Lincoln School two years after the start of construction.

The estimated investment in the project, with Passamaquoddy - 500-MW, Dickey-760-MW, and Lincoln School - 34-MW, would total approximately $896 million, including the transmission system with a cost of $87 million. The annual benefits would be $46.86 million of which $42.51 million is power, and $2.03 million recreation, $2.28 million area redevelopment and $0.04 million flood control benefits within the United States. With an allocation of about 10 percent to the recreation, area redevelopment and flood control benefits, the cost assigned to power could be repaid from power revenues within a period of 50 years after each unit becomes revenue producing, with interest at 3 percent per annum on the unpaid balance. The power would be marketed at load centers for $19.75 per kilowatt-year for capacity and 3.0 mills per kilowatthour for energy. This is lower than the cost of power provided by new modern steam electric powerplants, privately financed.

The logical development of the Upper Saint John River and the Passamaquoddy Project with the entire project financed by the United States as visualized in this report is engineeringly feasible and economically sound. It has a benefit-cost ratio of 1.47 to 1 of which the Upper Saint John River plants are 2.25 to 1 and Passamaquoddy is 1.04 to 1. These are based on current principles utilizing a 100-year project formulation period with interest at 3 percent. The repayment analysis is also based on 3 percent interest, with a payout period of 50 years after each power unit becomes revenue producing.

Equivalent power could be provided by alternative federally financed thermal power developments using either conventional fossil fuels or nuclear energy, which would be generally contrary to present practice and incompatible with the fundamental purposes of this report. Furthermore, it would not be a true alternative in conformance with the requirements of Senate Document No. 97, of which the following is quoted:

". . . . There is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes which would be precluded from development if the plan were undertaken. This limitation refers only to those alternative possibilities that would be physically displaced or economically precluded from development if the project is undertaken . . . ."

Such a Federal steam plant, if attainable, would waste the Nation's resources because it would lack the following fundamental benefits:

a. It would fail to utilize a significant undepletable resource and source of energy which is constantly being wasted to the sea by the rise and fall of the tides in Passamaquoddy Bay and in the flow of the Upper Saint John River on its course to the sea.

b. It would fail to provide the human appeal and economic impact so essential to stimulating the economy of the Maine area. It would lose the great catalytic effect of developing this tidal resource.

c. It would not provide the needed immediate employment opportunities to alleviate poverty in the seriously distressed conditions of Washington County and Aroostook County as would be accomplished from the Saint John and Passamaquoddy developments.

d. It could never attract and sustain recreational resource value for the area.

The tidal and river resource developments would be operated practically in perpetuity as all wearable parts can be replaced as necessary. At the end of the repayment period, the project will be in practically the same operating condition as it is in the start and the power can then be produced for only the cost of operation and interim replacements. Appropriate funds are being included in the project analysis to cover the operation and maintenance expense and to provide for the necessary replacements.

The Passamaquoddy Bay is not subject to siltation and filling, so its value will never be reduced from this cause. Its dams likewise for all practical purposes do not deteriorate in time.

The United States would fail in one facet of its leadership in overall energy development by neglecting to develop the vast energy in the Quoddy tides. Meanwhile, France will complete the La Rance Project and Russia is forging ahead in the development of its tidal projects.

CHAPTER III

RECOMMENDATIONS

We recommend that immediate steps be taken towards the following:

1. Early authorization of the International Passamaquoddy Tidal Power Project, the Upper Saint John River Developments, and the Transmission System, for construction by the United States. The Corps of Engineers should be authorized to construct the basic project features and the Department of the Interior should construct the transmission lines and market the power.

2. Early construction of the project to develop low cost firm power for Maine and peaking power for the remainder of the New England States, combat poverty, develop recreation resources, and utilize the now-wasted water resources of Maine.

CHAPTER IV

PROJECT FEATURES

The project combination selected consists of the Passamaquoddy development with reversible pump-turbines, the Dickey reservoir and powerplant, the Lincoln School reregulating reservoir and powerplant, and a transmission system interconnecting these powerplants and delivering power to load centers in Maine and in the vicinity of Boston, Massachusetts. Each feature is discussed in the following paragraphs:

a. Passamaquoddy

The designs and engineering studies for the Passamaquoddy Tidal Power Development are based on the International Joint Commission's report of April 1961. It includes Passamaquoddy Bay as the High Pool and Cobscook Bay as the Low Pool with two identical powerhouses, one at Carryingplace Cove and the second at Bar Harbor. The powerhouses are the only features which differ from the IJC plan.

Nearly seven miles of rock-filled dams will be required, a small portion of which would vary in depths ranging from 125 to 300 feet. The tidal velocities will range as high as 10 feet per second during the 26 foot high tide presenting engineering and design challenges without precedent. The Corps of Engineers, the

Bureau of Reclamation, the Bureau of Yards and Docks, the principal Federal engineering and construction agencies are confident that the tidal project can safely be constructed as concluded in the International Joint Commission's report.

As described in the IJC report, outstanding specialists in the fields of hydraulic engineering and soils mechanics were consulted and model studies were made to determine the best and most economical designs and methods of construction.

The project plan includes 90 filling gates, 40 in Letite Passage and 50 between Western Passage and Indian River. In the reach between Pope and Green Inlets, 70 emptying gates similar to the filling gates, but set at a lower elevation, would empty the lower pool.

Four navigation locks would be provided. The dimensions and locations were selected to accommodate present traffic in Passamaquoddy and Cobscook Bays with an allowance for a modest increase in the size of ships using the area.

The initial 50-unit powerplant will be at Carryingplace Cove and the second identical unit at Bar Harbor. The locations are shown in the Corps of Engineers' report included in this document. A closure dam would connect the west end of the powerhouse to the mainland.

Reversible pump-turbine units were selected for installation in the powerhouses between the Upper and Lower Pool in order to provide flexibility in operation and utilization of the full installed capacity of the project. This is described in Chapter V (a) and in the Corps of Engineers' report.

b. Dickey

The site selected for the Dickey Dam and 760-Mw powerplant is on the Upper Saint John River near Dickey, Maine, above the confluence of the Allagash River.

The main dam across the river and the dikes across the adjoining saddles would be of the earthfill type. All structural features would be located on the right bank and in general founded on rock; the low level outlet tunnels, which would be used for diversion during construction; the powerhouse with tailrace discharging into the Saint John River; and the spillway which would discharge during severe floods through a stilling basin into the lowermost 1-1/4 mile segment of the 100-mile Allagash River.

The Allagash River, located in the backwoods of northern Maine, is one of the few remaining free-flowing streams of importance in the eastern United States. It is a major recreation resource of great potential significance to the Nation.

If the Allagash is not preserved, it will mean that the Nation has lost access to an adventuresome outdoor experience which it has treasured since early times.

c. Lincoln School

The Dickey powerplant, with an ultimate installed capacity of 760-MW will have an average regulated flow of 4,370 c.f.s. with a maximum discharge of about 48,000 c.f.s. In order that the Dickey discharge might be better controlled and utilized, a re-regulating reservoir would be required. An ideal site was found approximately 11 miles downstream on the Saint John River at Lincoln School. Here a dam will be constructed, including a 34-MW powerhouse, that will impound the Dickey discharges and where the discharge will be regulated for more effective use by existing and proposed downstream hydroplants at Grand Falls and Beechwood, New Brunswick.

d. Transmission

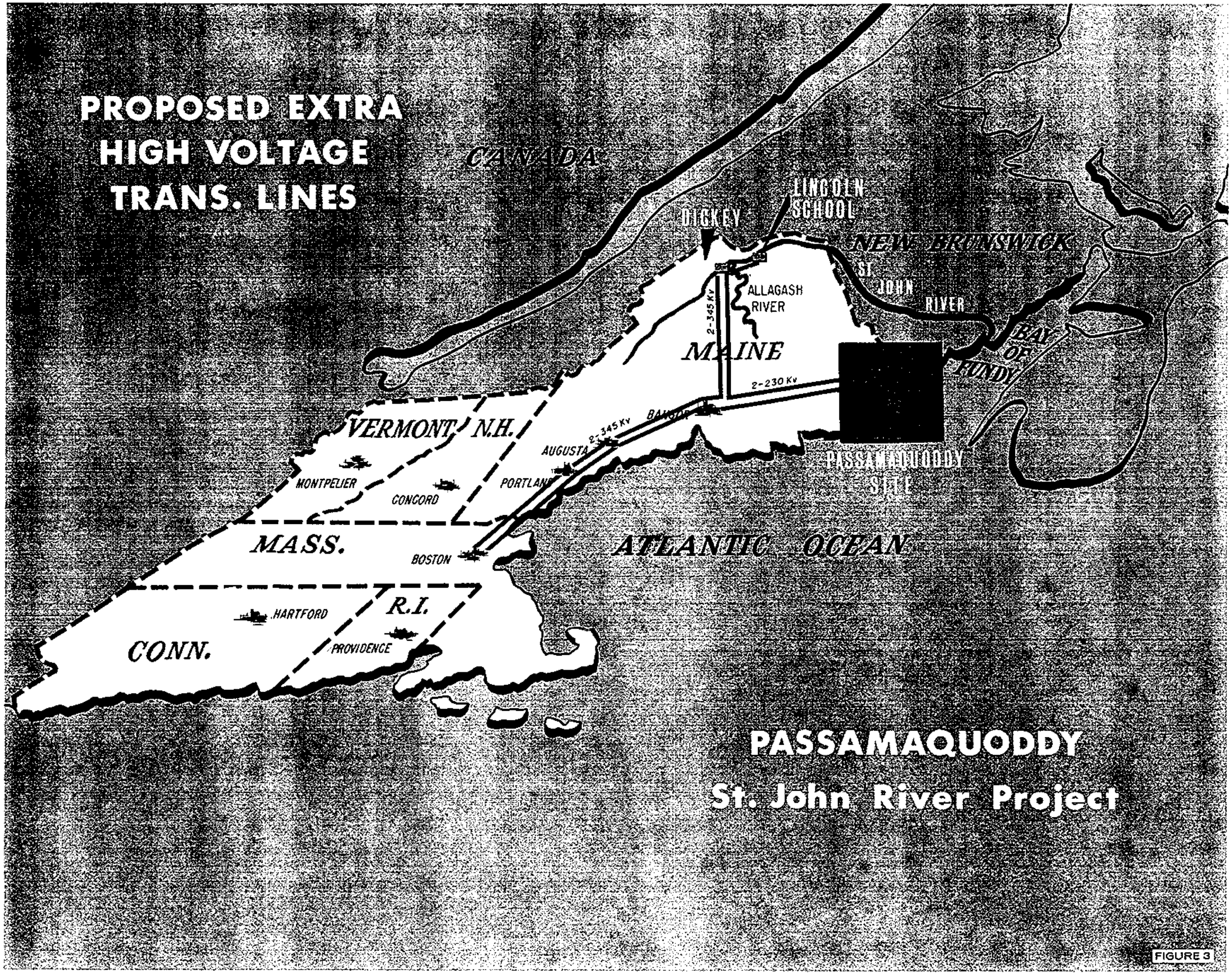
A strong transmission system is of the utmost importance to this project. It is required for electrical interconnection of the generating plants to permit fully coordinated and integrated operation and for delivery of power to load centers. Since the quantities of power involved are large and the distances are great, it is necessary to use EHV - extra high voltages.

The transmission system, as shown on Figure 3, would consist of two 345-KV transmission lines for the 410 miles from the Dickey-Lincoln School powerplants to the Boston area via Bangor, Augusta and Portland, Maine, and two 230-KV lines 90 miles between Passamaquoddy and Bangor, Maine. These transmission facilities would be required for a 500-MW development at Passamaquoddy, with the full development of 760-MW at Dickey and 34-MW at Lincoln School.

The transmission system was designed by the Bureau of Reclamation based on network analyzer studies. Appropriate reactive correction has been added to assure stable operation under fault conditions. The design visualized interconnections with the power systems in the New England area, as well as with Canada; however, no transmission lines have been included in the cost estimates for interconnection with the New Brunswick Electric Power Commission pending interconnection agreements with the Canadian Government for construction of the project and sharing of the power benefits.

The transmission system linking the New Brunswick system with the New England power systems will increase the reliability of both systems. This could reduce the amount of system reserve required and provide other economies which accrue from interconnected and integrated operation. While the values of such an interconnection are significant, none of these benefits were evaluated or included in the current analysis.

The transmission system was designed and the cost estimates were prepared on the basis of a Reconnaissance Field Survey and broad assumptions as to distribution of power to the load centers. Certain portions of the lines can be utilized for wheeling and will provide additional revenues for the project. These revenues were not evaluated. This fact will be recognized and considered as contracts for the sale of power are negotiated. The transmission system design should include such excess capacity as can be judiciously included to provide for potential revenue from the sale of "excess" peaking capacity and "off-peak" capacity.


PROPOSED EXTRA
HIGH VOLTAGE
TRANS. LINES
CANADA
DICKEY
LINCOLN
SCHOOL
NEW BRUNSWICK
ST. JOHN RIVER
ALLAGASH
RIVER
2-345 Kv
MAINE
2-230 Kv
BAY OF FUNDY
VERMONT
N.H.
AUGUSTA
2-345 Kv
BANGOR
MONTPELIER
CONCORD
PORTLAND
PASSAMAQUODDY
SITE
MASS.
BOSTON
ATLANTIC OCEAN
R.I.
HARTFORD
PROVIDENCE
CONN.
PASSAMAQUODDY
St. John River Project
FIGURE 3

CHAPTER V

HYDROLOGY AND OPERATING PLAN

The tides of Passamaquoddy Bay and the streamflows of the Upper Saint John River in Maine constitute the energy source for this project. The tides being astronomic in origin are dependable as to occurrence and predictable in magnitude depending upon the relative positions of the earth, moon and sun. The streamflows on the other hand follow no fixed pattern and depend on the rainfall and other hydrologic factors.

The basic operating plan envisions using the two-pool plan generally as set forth in the IJC report for the tidal development and utilizing storage control to regulate the releases and provide head for the river development. In the tidal plan, the Upper Pool is filled during the rising tide and water is allowed to flow from the Upper Pool to the Lower Pool through turbines for the generation of power. Evacuation of the Lower Pool will occur during the low tides. The river plan consists of controlling the streamflow, thereby diminishing flood hazards and allowing the water to flow through turbines for power generation. The power generated would depend on the streamflow and the head through which the water falls, which in turn depends upon the topography of the area.

a. Passamaquoddy

The Department's report of July 1963 envisioned the use of the two-pool plan for Passamaquoddy and the operation of the project to produce peak power of one hour's duration in the magnitude of 1,000-MW. As a result of the further studies concerning marketing possibilities, the engineering and economic analysis in this report was made for a power peak of two hours' duration.

Hydrologic studies using high speed electronic computers indicated that dependable capacities as shown in Table 5-1 could be obtained for two hours' duration with installed capacities of 300 to 1,000-MW. Limitations are placed on this operation during the period of neap tide. By using reversible pump-turbine units, the water level between the pools can be raised during the neap tide beyond that obtainable from the tides alone. This increases the head available for generation of power during the neap tides. Thus, the Passamaquoddy powerplant can be operated at the full installed capacity at the powerplant during all peaking periods.

Table 5-2 shows the results of operation with pumping under the following criteria:

1. The low pool is drawn down during the low tide occurring before the peaking periods.

2. During the high tide preceeding this low tide, the low pool is filled from the ocean and water pumped from the low pool to the high pool.

3. A 30 percent pumping efficiency was used.

Should the Passamaquoddy Project be operated for the generation of the maximum amount of energy rather than peaking power, the following quantities in millions of kilowatt hours should be obtained:

Number of turbine units	Energy production in GWH (1 million Kwh) Annual	9-month period
30	1,840	1,380
50	2,170	1,630
70	2,280	1,710
100	2,360	1,770

Assuming the Passamaquoddy Powerplant is operated to produce the maximum energy for 9 months of the year and peaking for 3 months as suggested by the FPC, which is considered a practical operation, the following would be obtained for an installation of 500- MW:

Peaking Capacity	500-Mw
Generation -	
9 months energy	1,630 GWH
3 months peaking energy	85
3 months off-peak energy	217
	1,932 GWH

Table 5-1

Passamaquoddy Power Generation (No pumping)

October * 1937	Installed Capacity - MW: 300	500	700	1,000
	2-Hour Peaking			
1	300	440	530	610
2		500	620	720
3			670	780
4			700	840
5				1,000
6				1,000
7			700	1,000
8	300	500	660	820
9	260	370	500	610
10	220	300	380	440
11	190	260	320	370
12	170	240	290	330
13	180	260	310	350
14	220	300	370	430
15	250	350	420	490
16	300	400	480	560
17		500	580	670
18			700	820
19				950
20				1,000
21				
22				
23				1,000
24			700	890
25		500	560	640
26		410	480	530
27		410	500	590
28		440	530	620
29		440	530	610
30		450	540	630
31	300	490	580	680

ENERGY FOR MONTH - MILLIONS OF KILOWATTHOURS

	300	500	700	1,000
Peak	17.380	27.120	35.100	43.960
Off-Peak	79.288	100.868	95.759	91.625
TOTAL	96.668	127.988	130.859	135.585

* October 1937 was selected because the mean tide range, as well as the frequency distribution of the ranges, approximates the long term observed values.

Table 5-2
PASSAMAQUODDY TIDAL POWER PROJECT
PUMPING POWER REQUIREMENTS
FOR PUMPING FROM LOW POOL TO
HIGH POOL DURING PERIODS OF
NEAP TIDE

50 Turbine Units - 2 Hour Peaking Duration

Oct 1937	Assumed placement of days	Energy production in MWH		Energy requirement for pumping in MWH
		Peak	Off Peak	
1	Saturday	800	1,390	0
2	Sunday	1,000	3,812	0
3	Monday	1,000	4,101	0
4	Tuesday	1,000	4,185	0
5	Wednesday	1,000	4,209	0
6	Thursday	1,000	3,130	0
7	Friday	1,000	3,074	0
8	Saturday	1,000	1,259	0
* 9	Sunday	0	0	1,950
10	Monday	1,000	0	550
11	Tuesday	1,000	0	2,250
12	Wednesday	1,000	0	2,100
13	Thursday	1,000	0	1,700
14	Friday	1,000	0	1,050
15	Saturday	585	0	0
16	Sunday	756	725	0
17	Monday	1,000	3,697	0
18	Tuesday	1,000	4,153	0
19	Wednesday	1,000	4,830	0
20	Thursday	1,000	5,245	0
21	Friday	1,000	5,368	0
22	Saturday	1,000	4,027	0
23	Sunday	1,000	4,443	0
24	Monday	1,000	4,494	0
25	Tuesday	1,000	2,072	0
26	Wednesday	1,000	0	450
27	Thursday	1,000	0	800
28	Friday	1,000	630	700
29	Saturday	880	2,300	0
30	Sunday	980	2,776	0
31	Monday	1,000	3,680	0
Total		29,001	73,600	11,550
3-month period 91.249 days		85,365	216,643	33,997

* No peaking power needed

The Passamaquoddy operation is extremely flexible. Computer studies prepared by the Bureau of Reclamation indicate that this operation can be coordinated and integrated with the Dickey powerplants to produce significant blocks of load factor power. The quantities of power will depend on the installed capacity in the Dickey unit and the installed capacity in Passamaquoddy. The following tabulation indicates the quantities of load factor power which could be obtained under these operations without utilizing the internal pumping features on the Passamaquoddy development.

2 Hour Peaking

Capacity			
Dickey	Passamaquoddy	Load Factor Power 50%	Peaking Power
475-MW	300-MW	130-MW	300-MW
570-MW	500-MW	260-MW	500-MW
760-MW	500-MW	159-MW	1111-MW

b. Dickey

The drainage area above the Dickey site is 2,725 square miles. At maximum elevation of 910 the reservoir area would be 88,600 acres and its capacity 8,080,000-acre feet. At drawdown level of 870 the reservoir area would be 58,500 acres and its capacity 5,180,000-acre feet.

The regulated flow available at the Dickey site was developed for periods of deficient streamflow, using records of flow at the Dickey gauging station. The critical periods were 1947 to 1948 and 1955 to 1958. The storage and regulated flow for various values of drawdown are:

Maximum Drawdown (feet)	Active Storage (acre-feet)	Regulated Flow (c.f.s.)
10	845,000	2,520
20	1,600,000	3,560
30	2,300,000	4,100
40	2,900,000	4,370

In computing the regulated flows, an allowance of 50 c.f.s. was made for losses by evaporation and leakage. For the selected maximum drawdown of 40 feet, the active storage would be 2.9 million acre-feet, and the regulated flow 4,370 c.f.s.

The annual energy generated with the full installation of 760-MW is 750 million kilowatthours annually.

c. Lincoln School

The active storage capacity of 16,000 acre-feet at Lincoln School would be sufficient for reregulation of the discharges from Dickey on a monthly basis. The controlled average outflow from Lincoln School would equal the regulated flow from Dickey plus the minimum flow, 200 c.f.s., from the Allagash River drainage area of 1,361 square miles. The 2,900,000 acre-foot active storage, 40-foot maximum drawdown, at Dickey would permit a regulated average flow of 4,370 c.f.s. after deducting 50 c.f.s. for evaporation and leakage. Thus the regulated average flow from Lincoln School would be 4,570 c.f.s.

The average energy generated with an installation of 34-MW at Lincoln School is 260 million kilowatthours annually.

CHAPTER VI

PROJECT PURPOSES

Substantial power, flood control, recreational and area redevelopment benefits will be provided by this multipurpose project. Each of these will have a significant impact on the area.

a. Power

Electric power will constitute the major benefit from this project and will provide the revenues for repayment of all costs except the approximate 10 percent allocated to area redevelopment, recreation and flood control. The need and marketability of the power generated is described in the chapter on "Marketing." The economics are covered under "Economic and Financial Analysis."

The power generated will be predominantly "peaking" power but substantial quantities of both load factor and off-peak power can be produced. The operation is quite flexible and can be coordinated readily with other generation sources in the area. Its long term predictability enhances the effective utilization of the tidal resource for the peaking power.

b. Flood Control

The Saint John River rises in the Appalachian Mountains at Little Saint John Lake on the international boundary between the United States and Canada. The total fall from its source in Little Saint John Lake and tidewater at Fredericton is about 1,578 feet. The total drainage area is about 21, 300 square miles, of which 7, 600 square miles is in the State of Maine. There are 2, 725 square miles in the drainage area above the Dickey site and 1, 500 square miles in the Allagash River Basin.

The Dickey reservoir with a capacity of 8, 080, 000 acre-feet, of which 2, 900, 000 acre-feet is active storage at a maximum draw-down of 40 feet, will provide full regulation of the streamflow at the Dickey site.

Snowmelt, sometime in combination with rainfall, annually produces spring floods along the Upper Saint John River. These would be controlled by the proposed reservoir. Since the area has been sparsely settled, significant damages have only occurred at Fort Kent, which is located about 28 miles downstream from the Dickey dam. The Fort Kent urban area has experienced seven consequential floods during the past 36 years of record. Two of the largest floods have occurred within the past five years, the most damaging being in 1961, a recurrence of which would cause damages at today's prices of $450, 000.

Damages at Fort Kent start at a river discharge of 100, 000 c. f. s. The 1961 discharge was 131, 000 c. f. s. Inasmuch as the Dickey dam controls 47. 5 percent of the contributing drainage areas impoundment of flood waters would reduce discharges to well below the damage stage.

The alternate method for prevention of damages, without reservoirs, would be a local protection project. A recent study investigation by the New England Division, Corps of Engineers, in 1963 indicated that such a project would cost $1,060,000. Dickey dam would make such a project unnecessary and the flood control benefits at Fort Kent would average $40,000 annually.

The flood protection afforded by Dickey dam will also benefit the Lower Saint John River. The actual extent of flood protection afforded along the Lower Saint John River should be studied in detail and evaluated in the course of negotiations with the Canadian Government.

c. Recreation

The recreational values of the potential Passamaquoddy Tidal Power Project have been studied by the Department of the Interior's Bureau of Outdoor Recreation and are described in the July 1963 report.

The principal attraction to tourists would be the tidal project. This unique attraction and engineering marvel would feature the rise and fall of the tides, the impounding of water in two natural pools, navigation locks for unrestricted movement of boats, emptying and filling gates, and power transmission. Parking areas, picnic sites and boat launching ramps would be provided. Service roads to the various features would offer sightseeing opportunities to the area. Representative statistics on recreational use of several water resource projects in other parts of the Nation are as follows:

Project	State	Total Visitor Days-1962
Central Valley	California	5,209,923
Boulder Canyon	Arizona-Nevada	3,200,739
Colorado-Big Thompson	Colorado	1,593,653
W. C. Austin	Oklahoma	1,295,079
Rio Grande	New Mexico	1,210,000
Solano	California	865,720
Rapid Valley	South Dakota	605,300

Recreational facilities could also be provided at the Dickey reservoir site as camping areas and boat launching ramps.

d. Area Redevelopment Benefits

Washington County, the location of the Passamaquoddy Tidal Powerplant, and Aroostook County, where the Dickey site is located, have been declared areas of substantial and persistent unemployment. Washington County's population has declined for the decade 1950 to 1960, while Aroostook County's population increased only by 9.4 percent--as contrasted to a national growth rate of 19.2 percent.

Economic opportunity has been denied to the youth of both counties with subsequent migration to other cities and states, thus breaking down the traditional family solidarity characteristic of New England. Industry has moved to other areas, thereby causing many retail and service establishments to close. The high cost of electric power has been a significant contributing factor in the industrial decline of the area. Fish processing plants in Washington County--an important local industry--have gone out of business, and the county's agricultural economy has been declining. In Aroostook County, agricultural conditions are uncertain, and the lumber industry is subject to wide fluctuation.

A national sampling conducted by the Department of Labor in 1959 shows that an annual income of approximately $6,000 is required to maintain a modest but adequate level of living for a typical family of four. In Washington County, 34 percent of the families have incomes of less than $3,000 annually, and in Aroostook County over 30 percent of the families have incomes of less than $3,000. In Washington County, nearly 17 percent of the family units receive some form of public assistance, and in Aroostook County nearly 12 percent of the family units receive public assistance. Using this yardstick, one-third of the people in the area live in poverty, as contrasted with a national projection of one-fifth.

By providing substantial on-site employment, the Passamaquoddy-Dickey Project will do much to alleviate human misery. The area redevelopment values, however, go much further than employment opportunity. The Department of the Interior's experience in 60 years of water resource development has conclusively demonstrated that for each dollar of Federal investment an additional two dollars of private business is stimulated. Furthermore, a rejuvenated economy normally follows completion of water resource projects.

More important, perhaps, for longer term is the new ray of hope which will be instilled in the people of the area--men, women, and children who have lived with a mounting sense of despair for years. The psychological exit from poverty provided by Quoddy-Dickey, as well as its material benefits, will again offer the self-reliant people of the area a new opportunity to advance themselves to the limits of their capabilities.

e. Effect on Fisheries

The International Joint Commission's report of April 1961 described in detail the effect of the two-pool tidal powerplant operated on the basis of producing continuous power and evaluated the damages to fishing under the project's operation. The general conclusion of the previous report was as follows:

> "On the basis of the extensive studies of the Fisheries Board, the Commission finds that by providing for relocation and modification of existing fisheries facilities and by including appropriate remedial measures in the design of the tidal power structures, construction and operation of the tidal power project would have very little effect on the important sardine industry in the region and only a minor effect on other fisheries."

In answer to the question as to how the changes in the present proposal might affect the fisheries of the Passamaquoddy area, a working party of United States and Canadian fishery scientists was formed at a meeting in Ottawa, Canada, December 4 - 5, 1963, and asked to study the problem. This group, composed of Drs. J. L. Hart and L. Chenard of Canada, and Messrs. D. L. McKernan and L. W. Scattergood of the United States, reports the following:

> "Changes in the Fisheries
>
> Although the Interior plan will produce minor differences in oceanographic conditions compared to the IJC proposal, and the overall influence may be slightly less favorable, it is concluded that previous predictions contained in the IJC report concerning the effect of the project on the fisheries of the area are generally valid."

This report was forwarded to the Canadian and United States Governments. The report to the Secretary of the Interior was dated April 21, 1964.

CHAPTER VII

COST ESTIMATES

This chapter summarizes the estimates of cost, as of January 1964, prepared by the Corps of Engineers for the Passamaquoddy Tidal Power Project and the hydroelectric powerplants on the Upper Saint John River at Dickey, Maine, and Lincoln School. It also summarizes the estimates of cost for the transmission system prepared by the Bureau of Reclamation.

The layout and design of the tidal project is the same as proposed by the International Joint Commission with the exception of the powerplant. Four sizes of powerplants are considered; namely, thirty, fifty, seventy and one-hundred units of 10,000-KW each. Thirty or fifty units would be located in Powerhouse No. 1 and the additional units to make up the seventy or one-hundred units would be located in Powerhouse No. 2.

The proposed dam at Dickey, **along with the reregulating dam** at Lincoln School, are new layouts and designs.

The transmission system estimate includes the lines and substation necessary to market the power generated from the project in the United States. Depending upon agreements with Canada for sharing of power, the transmission system could be modified to include other lines interconnecting the United States and Canadian systems.

ESTIMATE OF COST

TIDAL POWER PROJECT

Item	Cost in Thousands Installed Capacities 300-MW	500-MW	700-MW	1,000-MW
Powerplant	$ 119,189	$ 204,491	$ 302,287	$ 427,162
Switchyard	1,780	2,370	3,160	3,950
Filling Gates	62,634	62,634	62,634	62,634
Emptying Gates	57,627	57,267	57,627	57,627
Locks	18,917	18,917	18,917	18,917
Dams	77,309	63,664	64,454	64,454
Lubec Channel	634	634	634	634
Fishways	888	1,298	1,748	2,324
Service Facilities	1,670	1,870	2,070	2,470
Relocations	3,929	4,931	7,431	9,631
Lands and Damages	1,870	1,870	1,960	2,030
Subtotal	$ 346,447	$ 420,306	$ 522,922	$ 651, 833
Contingencies	49,520	58,967	72,728	89,616
Subtotal	$395,967	$ 479,273	$ 595,650	$ 741, 449
Engr., Design Supervision & Administration	43,478	50,581	61,221	74,482
TOTAL FIRST COST	$439,445	$ 529,854	$ 656,871	$815,931
Interest during Construction	33,225	39,267	45,966	53,824
	$ 472,670	$569,121	$ 702,837	$869,755

ESTIMATE OF COST

DICKEY PROJECT

Item	Cost in Thousands Installed Capacities			
	190-MW	380-MW	475-MW	760-MW
Lands and Damages	$ 4,469	$ 4,469	$ 4,469	$4,469
Relocations	1,363	1,363	1,363	1,363
Reservoir Clearing	2,000	2,000	2,000	2,000
Dams	72,919	72,919	72,919	72,919
Penstocks	3,624	7,249	9,062	14,503
Powerplant	28,531	39,093	44,591	60,229
Switchyard	1,583	1,940	2,787	3,466
Buildings, Grounds & Facilities	560	560	560	560
Access Roads	728	728	728	728
Subtotal	$115,777	$130,321	$138,479	$160,237
Contingencies	16,935	18,691	19,700	22,321
Subtotal	$132,712	$149,012	$158,179	$182,558
Engr., Design Supervision & Administration	14,954	16,559	17,476	19,880
PROJECT FIRST COST	$147,666	$165,571	$175,655	$202,438
Interest during construction	6,500	7,036	7,337	8,128
	$154,166	$172,607	$182,992	$210,566

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Cost in Thousands
Lands and Damages	$ 400
Relocations	1, 238
Reservoir Clearing	40
Dams	4, 323
Powerplant	6, 290
Switchyard	387
Buildings, Grounds and Facilities	208
Access Roads	50
Subtotal	$12, 936
Contingencies	1, 776
Subtotal	$14, 712
Engineering, Design, Supervision and Administration	1, 553
PROJECT FIRST COST	$16, 265
Interest during construction	480
	$16, 745

PASSAMAQUODDY OPERATION, MAINTENANCE AND REPLACEMENT COST

	Installed Capacity 300-MW	Installed Capacity 500-MW	Installed Capacity 700-MW	Installed Capacity 1,000-MW
Operation & Maintenance	$1,126,000	$1,340,000	$1,540,000	$1,910,000
Replacements	333,000	508,000	693,000	970,000
Total OM&R	$1,459,000	$1,848,000	$2,233,000	$2,880,000

DICKEY AND LINCOLN SCHOOL PROJECTS OPERATION, MAINTENANCE AND REPLACEMENT COST

	Installed Capacity 190-MW	Installed Capacity 380-MW	Installed Capacity 475-MW	Installed Capacity 760-MW
Operation & Maintenance	$ 400,000	$580,000	$670,000	$940,000
Replacements	38,000	74,000	92,000	145,000
Total OM&R	$ 438,000	$654,000	$762,000	$1,085,000

LINCOLN SCHOOL PROJECT

	Installed Capacity 34-MW
Replacements	$12,800

TRANSMISSION

Investment	$ 84,492,000
Interest During Construction	2,535,000
Total Investment	$ 87,027,000
Annual Operation and Maintenance	$ 489,000
Replacements	87,000
O&M and Replacements	$ 576,000

PASSAMAQUODDY POWERPLANT

Added Cost For Inclusion of Reversible Turbine Features

Investment (50 Units)-(including interest during construction)	$ 12,880,000
Amortization - Annual	$ 407,650
Operation and Maintenance & Replacements	62,350
Annual Costs	$ 470,000

CHAPTER VIII

ECONOMIC AND FINANCIAL ANALYSIS

The economic justification and financial feasibility of the potential project have been analyzed using current evaluation procedures. A 100-year period of analysis and a 3 percent Federal interest rate were used in the economic studies. In accordance with the provisions of Senate Document No. 97, recreation and area redevelopment were included as project purposes.

a. Project Formulation

The optimum development for the Passamaquoddy-Dickey project under current evaluation criteria was determined to consist of the following project segments:

(1) Dickey Dam, Reservoir, and Powerplant with eight generating units having a total installed capacity of 760-MW;

(2) Lincoln School Regulating Reservoir and Powerplant with two generating units of 17-MW each;

(3) Passamaquoddy Tidal Basin facilities and powerplant with 50 - 10-MW generating units; and

(4) Transmission facilities required to distribute project-produced power and energy to load centers in Maine and Massachusetts.

The proposed Dickey development represents maximum utilization of the Saint John River in Maine consistent with preservation of the wild river characteristics of the Allagash. The proposed development of Passamaquoddy represents only an initial step toward development of the full power potential. Construction of Passamaquoddy as proposed in this report envisions the construction of the second powerplant when future conditions warrant such development.

Well established project formulation procedures were followed in determining the optimum economic development of the project. The objective of these procedures is to insure that the benefits for each added segment of the project bear a favorable relationship to the cost for including the segment. Furthermore, the project is formulated at a level of development that will result in maximization of project benefits over costs.

Comparison of project benefits and costs for various size power installations at Dickey indicates that the installation of eight generating units is amply justified. Additional units were not considered because physical limitations preclude the installation of more than eight units.

Table 24 (cont.)

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Quantity	Unit	Unit Price	Amount
7. BUILDINGS, GROUNDS & FACILITIES			L.S.	$ 208,000
8. ACCESS ROADS			L.S.	$ 50,000
SUB-TOTAL				$12,936,000
Contingencies				1,776,000
SUB-TOTAL				$14,712,000
Engineering, design, supervision & administration				1,553,000
TOTAL PROJECT FIRST COST				$16,265,000

TABLE 8-1 PROJECT FORMULATION
DICKEY ANALYZED WITHOUT PASSAMAQUODDY

Item	Power Installation at Dickey			
	2 Units	4 Units	6 Units	8 Units
Installed Capacity	MW	MW	MW	MW
Dickey	190	380	570	760
Lincoln School	34	34	34	34
Total	224	414	604	794
Annual Benefits	$1,000	$1,000	$1,000	$1,000
Power	10,398	15,162	19,924	24,688
Flood Control	40	40	40	40
Area Redevelopment	247	271	343	409
Total	10,685	15,473	20,307	25,137
Incremental	--	4,788	4,834	4,830
Annual Project Costs				
Dickey	5,267	6,067	6,941	7,699
Lincoln School	593	593	593	593
Transmission System	671	2,018	2,870	2,870
Total	6,531	8,678	10,404	11,162
Incremental	--	2,147	1,726	758
Benefit-Cost Ratio				
Total	1.64	1.78	1.95	2.25
Incremental	--	2.23	2.80	6.37

Passamaquoddy was then analyzed as an increment to the Dickey unit development. The result of this analysis is shown in Table 8-2. It will be noted that Passamaquoddy with a power installation of 500 MW constitutes a justifiable increment to the project. Power installations of 700 MW and 1,000 MW were also considered but it was concluded that these should be reappraised at some future time when the power demand grows and further experience is gained by the utility systems in meeting peaking power requirements. Since the initial 500-MW powerplant does not preclude later additions in the second powerplant, considerations of the full development can readily be deferred.

Internal pumped-storage features were included in the proposed plan of development for Passamaquoddy because the analysis of incremental benefits and costs associated with these features revealed that for a relatively small expenditure, project benefits would be enhanced greatly.

Information was obtained on the cost of developing equivalent supplies of energy and capacity by alternate means. The estimated cost of producing power by the proposed Dickey-Passamaquoddy project is significantly lower than modern conventional steam plants under private financing. Nevertheless, it would be possible to produce the equivalent power at less cost in federally-financed conventional steam plants. However, the two types of developments would not be at all comparable in terms of the effects on water resource development, flood control, recreation and area redevelopment.

Passamaquoddy, in particular, constitutes a unique resource potential. Construction of steam plants would still leave this unique resource undeveloped and the highly significant impact of recreation and area redevelopment on the economy of the State of Maine would be foregone. Therefore, it can be concluded that the interests of the United States would not be served nearly as well by the construction of federally-financed steam plants in New England.

The basic objective in the formulation of plans is to provide the best use, or combination of uses, of water and related land resources to meet all foreseeable short and long-term needs. National and economic development and the development of each region within the country are essential to the maintenace of national strength and the achievement of a satisfactory level of living. Water and related land resource development and management are essential to these aims. The well being of all people shall be the over-riding determinant in considering the best use of water and the related land resources. Construction of a steam plant as an alternate to the Passamaquoddy-Dickey Project would not contribute to the foregoing aims.

TABLE 8-2 PROJECT FORMULATION
INTEGRATED* OPERATION--DICKEY AND PASSAMAQUODDY
WITH PUMPED STORAGE (TWO-HOUR PEAKING)
(Based on 100 year Project Formulation)

Item	8-Unit Dickey with Trans. **	Integrated Operation Dickey plus	
		30-Unit Quoddy	50-Unit Quoddy
Installed Capacity	MW	MW	MW
Dickey plus Lincoln School	794	794	794
Quoddy	--	300	500
Total	794	1,094	1,294
Annual Benefits	$1,000	$1,000	$1,000
Power	24,688	36,732	42,511
Flood Control	40	40	40
Area Redevelopment	409	1,845	2,278
Recreation	--	2,030	2,030
Total	25,137	40,647	46,859
Incremental	--	(15,510)	21,722
Annual Project Costs			
Dickey plus Lincoln School	8,292	8,292	8,292
Quoddy	--	16,700	20,334
Transmission System	2,870	3,330	3,330
Total	11,162	28,322	31,956
Incremental	--	(17,160)	20,794
Benefit-Cost Ratio			
Total	2.25	1.44	1.47
Incremental	--	(0.90)	1.04

* Pumping to Upper Pool from Lower Pool during periods of neap tides, only.

** Transmission to Boston, Massachusetts area.

b. Benefits and Costs

Construction of the proposed Passamaquoddy-Dickey power development would create annual equivalent benefits of $46,859,000. (This includes power benefits analyzed under a two-hour peaking operation at Dickey and Passamaquoddy.) The associated annual equivalent Federal project costs are $31,956,000. The resulting benefit-cost ratio is 1.47 to 1.

c. Purposes

Benefits creditable to the project were analyzed for five project purposes--power, recreation, area redevelopment, flood control, and fish and wildlife. A discussion of the benefits for each of these purposes follows.

1. Power Benefits

The annual power benefits creditable to the proposed Passamaquoddy-Dickey developments are estimated to be $42,511,000 based on the standard energy-capacity approach. The annual value of capacity and energy that would be produced by the project was computed using energy and capacity unit values furnished by the Federal Power Commission. These unit values represent the alternative costs of producing energy and capacity in New England from highly efficient, large-scale, conventional steam plants under private financing. Inasmuch as transmission system costs have been included in the project cost estimates, power benefits have been computed for at-market conditions. Transmission losses of 9.5 percent for capacity and 7.1 percent for energy were deducted in the power benefit analysis.

Composite at-market unit power values of 3.0 mills per kilowatt-hour of energy and $27.70 per kilowatt of dependable capacity were adopted for use in evaluating power benefits. These composite values reflect the projected amounts of energy and capacity produced by the project that would be marketed in Boston and Maine power load centers.

Energy Values	Mills/KWH
Maine	3.31
Boston	2.79
Composite	3.00

Capacity Values	Dollars/KW
Maine	29.51
Boston	26.02
Composite	27.70

Estimates of dependable capacity, average annual energy generation, and power benefits are summarized in Table 8-3.

Table8-3. Power Benefits and Related Data
Proposed Passamaquoddy-Dickey Power Developments
Two-Hour Peaking Operation

Item	Amount
Installed Capacity	MW
Dickey	760
Lincoln School	34
Passamaquoddy	500
Dependable Capacity	1,294
Average Annual Energy	MWH
At-Site Production	2,908,000 *
Downstream Production	656,000
Annual Power Benefits	$1,000
Capacity	32,439
Energy	10,072
Total	42,511

* Net production after deducting pumping energy used in pumped-storage operation at Passamaquoddy, **during neap tide periods.**

2. Recreation Benefits

The recreational aspects of the potential Passamaquoddy Tidal Development have been studied by the Bureau of Outdoor Recreation. This Bureau estimates the annual recreational visitation to Passamaquoddy would be 500,000 visitor-days under 1975 conditions. The number of visitors is expected to increase to 4,675,000 by the year 2025. The average annual benefits associated with this recreation activity adjusted for changes over time are estimated to be $2,030,000 based on recreational values of $0.80 per visitor-day.

3. Area Redevelopment Benefits

Both the Passamaquoddy and Dickey power developments are located within counties which are designated as "redevelopment areas" based on criteria set forth in the Area Redevelopment Act of 1961 (75 Stat. 47); therefore, construction of the potential project would significantly reduce unemployment in these two areas.

Current evaluation procedures require the measurement of benefits attributable to the value of labor required for the construction and operation of a project that otherwise would not be fully utilized. Such benefits are identified in this analysis as area redevelopment benefits.

In evaluating the benefits which would accrue from area redevelopment, wages paid to skilled and unskilled labor required for project construction and salaries paid to personnel for project operation were considered. Labor inputs necessary for the construction of the potential project were estimated through use of information obtained from the Corps of Engineers. Information on the present extent of unemployment in the affected labor-market areas and the character of the unemployed labor force was obtained from the Employment Security Commission, State of Maine. Utilizing this information, the available local unemployed labor force was compared with the projected construction work requirements by construction years to estimate the amount of increased employment of the local labor force creditable to project construction. The associated construction wages converted to annual equivalent values for a 100-year period of analysis were used as the construction employment component of the area redevelopment benefits.

Salaries and wages paid to the permanent operating personnel were estimated and used in evaluating the contribution of project operation to local employment. However, in accordance with current procedures of the Department of Commerce, the overall employment period was established at 20 years from initiation of construction at the Dickey and the Passamaquoddy sites, and a declining scale of values reaching zero in the 21st year was utilized. The employment benefits associated with project operation were evaluated as the annual equivalent of this series of declining values when spread over the 100-year period of analysis for the project. The annual area redevelopment benefits creditable to the Passamaquoddy-Dickey power development, as estimated in the manner described, are $2,278,000, annually.

Additional information relating to the area redevelopment analysis is presented in Table 8-4.

TABLE 8-4 Area Redevelopment Benefits
Passamaquoddy-Dickey Power Development

	Dickey	Passamaquoddy	Project Total
Local Labor Utilized, Construction			
Man Years	2,200	9,900	12,100
Total Wages	$9,630,000	$54,080,000	$63,710,000
Operation and Maintenance			
Annual Wages & Salaries	$562,000	$810,000	$1,372,000
Annual Equivalent Benefits			
Construction	$305,000	$1,712,000	$2,017,000
Operation & Maintenance	$104,000	$157,000	$261,000
Total Benefits	$409,000	$1,869,000	$2,278,000

4. Flood Control Benefits

Construction of Dickey Dam and Reservoir is expected to provide local flood control benefits at Fort Kent of $40,000 annually.

5. Fish and Wildlife Benefits

Fish and wildlife benefits are not included in the project. The costs for mitigating damages to fish and wildlife have been included as project costs and have been allocated as joint costs of the project.

6. Summary of Project Benefits

Purpose	Annual Equivalent Benefits
Power (two hour peaking)	$42,511,000
Recreation	2,030,000
Flood Control	40,000
Area Redevelopment	2,278,000
Total	$46,859,000

d. Federal Power Costs

Annual Federal costs associated with the benefits for the potential Passamaquoddy-Dickey power development are estimated at $31,956,000 based on a 100-year analysis and 3 percent interest. The derivation of this estimate is shown in the following tabulation:

Item	Costs ($1,000)
Construction Costs	
Dickey	202,438
Lincoln School	16,265
Passamaquoddy (with pumping modifications)	541, 881
Transmission System	84,492
Interest during Construction	
Dickey	8,128
Lincoln School	480
Passamaquoddy	40,170
Transmission System	2,535
Total Investment	$ 896, 389
Annual Equivalent Investment Costs	$ 28,370
Annual Operating Costs	
Dickey and Lincoln School	1,098
Passamaquoddy	1,912
Transmission System	576
Total Annual Equivalent Costs	$ 31, 956

e. Cost Allocation

The costs of the potential project have been allocated among the four functions of power, recreation, flood control and area re-development, using the separable costs-remaining benefits method of allocation, a 100-year period of analysis and three percent interest. The costs to be allocated are summarized below:

Project Facilities	Project Investment Costs			Annual Operating Costs
	Constr.	I. D. C.	Total	
	$1,000	$1,000	$1,000	$1,000
Dickey	202,438	8,128	210,566	1,035
Lincoln School	16,265	480	16,745	63
Passamaquoddy	541, 881	40,170	582,051	1,912
Trans. System	84,492	2,535	87,027	576
Total	845,076	51,313	896,389	3,586

The results of the cost allocation are summarized in Table 8-5, and the basic allocation is shown in Table 8-6.

TABLE 8-5 SUMMARY OF PROJECT COST ALLOCATION

Project Purpose	Construction	Int. During Construction	OM&R
Power	$751,077,000	$45,215,000	$3,505,000
Area Redevelopment	49,259,000	3,191,000	42,000
Recreation	43,887,000	2,844,000	38,000
Flood Control	853,000	63,000	1,000
Total Project	$845,076,000	$51,313,000	$3,586,000

TABLE 8-6 COST ALLOCATION
PASSAMAQUODDY-DICKEY POWER DEVELOPMENTS

Item	Project Functions				Total Project
	Power	Area Redevelop.	Rec.	Flood Control	
	$1,000	$1,000	$1,000	$1,000	$1,000
Costs to be Allocated					
Construction					845,076
I.D.C. *					51,313
OM&R					3,586
Annual Equivalent Values					
Benefits	42,511	2,278	2,030	40	46,859
Alternative Costs	31,956	**	**	**	-
Justifiable Expenditure	31,956	2,278	2,030	40	36,304
Separable Costs					
Construction	14,982	-	-	-	14,982
I.D.C.	863	-	-	-	863
OM&R	3,266	-	-	-	3,266
Total	19,111	-	-	-	19,111
Remaining Justifiable Exp.	12,845	2,278	2,030	40	17,193
Percentage	(74.71)	(13.25)	(11.81)	(0.23)	(100.00)
Remaining Joint Costs					
Construction	8,789	1,559	1,389	27	11,764
I.D.C.	568	101	90	2	761
OM&R	239	42	38	1	320
Total	9,596	1,702	1,517	30	12,845
Total Allocated Costs					
Construction	23,771	1,559	1,389	27	26,746
I.D.C.	1,431	101	90	2	1,624
OM&R	3,505	42	38	1	3,586
Total	28,707	1,702	1,517	30	31,956
Summary of Allocated Costs					
Construction	751,077	49,259	43,887	853	845,076
I.D.C.	45,215	3,191	2,844	63	51,313
OM&R	3,505	42	38	1	3,586

* Interest during construction, 3% per annum.
** Cost of alternative exceeds benefits, hence the justifiable expenditure is limited to the benefits.

f. Repayment

Reimbursable Costs

The construction costs and interest during construction allocated to power is $796,292,000 and is assumed to be fully reimbursable with interest. For fiscal year 1964, the applicable interest rate is 3 percent per annum.

The balance of the project construction costs and interest during construction, $100,097,000, is assumed to be nonreimbursable. Under existing statutes, costs allocated to flood control are nonreimbursable. It is proposed that the costs allocated to area redevelopment and recreation be authorized as fully nonreimbursable. However, if the costs allocated to recreation were made nonreimbursable only within the limits established in the proposed Bill, H. R. 9032, only $26,256,000 of the construction costs and $1,701,000 of the interest during construction allocated to recreation would be reimbursable.

Power Repayment

Power payout studies for the potential Passamaquoddy-Dickey power development were made to determine the rates at which the power would have to be marketed to achieve reimbursement of the power investment costs in 50 years. The power payout studies disclosed that power rates as shown below would be adequate to achieve repayment of the total power investment, including the transmission system, in 50 years after each unit becomes revenue producing. Moreover, the power payout studies disclosed that the rates would be adequate to achieve repayment of the power investment allocations for each stage of the development within its own 50-year repayment period.

The at-market power rates used in the power payout analysis are:

Energy	3.0 mills/kw-hr
Dependable Capacity	19.75/Kw

An annual revenue credit of $2 million for downstream generation in Canada was assumed in the power payout analysis for planning purposes only. However, unlike the analysis prepared for the July 1963 report, no credit was taken for wheeling revenues in the current power payout studies.

COMPARISON OF DICKEY AND PASSAMAQUODDY-DICKEY PROJECT COSTS WITH A FEDERALLY FINANCED STEAM ALTERNATE

The following cost estimates and comparisons were made to determine the cost of an equivalent quantity of power provided by the project, if generated from comparably financed (Federal) conventional steam plants.

Item	Annual Project Costs Federally Financed		Alternate Costs-Steam Federally Financed
	Total	Adjusted	Total
760-MW Dickey plus 34-MW Lincoln School	$11,162,000	$10,713,000 1/	$14,645,000
500-MW Passamaquoddy plus 760-MW Dickey and 34-MW Lincoln School	$31,956,000	$27,608,000 2/	$26,231,000

1/ Annual cost less flood control benefits of $40,000 annually and Area Redevelopment, $409,000 annually.

2/ Annual cost less flood control benefits of $40,000 annually, Recreation $2,030,000 annually and Area Redevelopment $2,278,000 annually.

CHAPTER IX

MARKETING

A project is valuable only to the extent of the need and demand of the goods or services produced. With this principle as a guide, the Passamaquoddy-Dickey project functions were evaluated. This discussion is directed to the major revenue producing feature - Power. Flood Control, Area Redevelopment and Recreational Benefits are discussed under other chapters of the report.

The Department of the Interior's Load and Resources Study, dated December 1961, recognized the merits and made the initial proposal for the Passamaquoddy Tidal Power Project operating primarily as a peaking powerplant to supply a large market area. These conclusions were based on a review of the International Joint Commission's Report of April 1961 and studies utilizing data obtained from the Washington and Boston offices of the Corps of Engineers, U.S. Army, the Washington and New York offices of the Federal Power Commission, and the headquarters office of the New Brunswick Electric Power Commission at Fredericton, New Brunswick.

The market area selected in the current studies embraces the New England States and the Maritime Provinces of Canada. The division of power will depend upon the agreements reached with Canada for construction of the project. In these studies, it is assumed that the additional power produced as downstream benefits will be marketed by the New Brunswick Electric Power Commission and all the other power will be marketed by the United States.

a. Load Studies

The Federal Power Commission Advisory Committee Report No. 13 forecast the electric utility power requirements in New England to the year 1980. It indicates that the State of Maine will experience a peak demand of 1,750 MW in 1980, with an energy requirement of 9.6 billion kilowatthours annually. The balance of New England, less the State of Maine, would have a peaking requirement in 1980 of 18,700 MW with 95 billion kilowatthours of associated energy. The load growth and generation required to meet the peak loads are shown in the following tabulation.

NEW ENGLAND LOAD GROWTH AND RESOURCES
FEDERAL POWER COMMISSION AND
EDISON ELECTRIC INSTITUTE DATA

	1960	1965	1970	1975	1980
			Megawatts		
Maximum Demand					
PSA 1 (Maine)	565	800	1,010	1,350	1,750
2 (Mass., Vt., R.I., Conn., N.H.)	5,616	7,900	10,400	14,050	18,700
	6,181	8,700	11,410	15,400	20,450
Installation required (15% Reserve)	7,280 (Actual)	10,000	13,200	17,700	23,600

Installed Capacity - MW
December 31, 1963 — 7,958

Additions Planned thru 1967 - Taken from Edison Electric Institute Publication No. 63-65 dated October 1963

Bangor Hydro	29	
Boston Edison	395	
Central Maine Power	125	
Conn. Light & Power	172	
Connecticut Yankee	460	
Hartford Electric Light	235	
New England Power Co.	496	
	1,912	+ 1,912
		9,870

b. Characteristics of Power Markets

The growth of utility power markets in New England and New Brunswick, as in the rest of the United States and Canada, is influenced by a number of economic and technological factors. These include growth of population and households; expansion of industrial production; growth of activities associated with service, trade, and professional establishments; greater application of known processes and devices using electricity; and the development and introduction of new uses for electricity in the home, industry, and other fields. Under the impact of these influences, the utility markets have grown steadily over a long period. The growth of these markets is expected to continue in the future.

At present there are 31 electric utilities operating in the State of Maine and 126 in the remaining New England States. In Canada, the principal utilities are the New Brunswick Electric Power Commission, the Nova Scotia Power Commission and the Nova Scotia Light and Power Company, Ltd.

The load shape forecast for New England, based on Federal Power Commission data projected for 1980, is indicated on the following chart:

This shows the predominantly high peak loads which must be met and indicates the potential for sale in excess of one million kilowatts for a peak of two hour's duration. This is predicated on load growth based on current expansion factors and does not take into account the economic impact of the project on the area.

Since the project's total capacity of 1,294-MW will provide 2.94 billion kilowatthours of energy annually, the project has 2,274 kilowatthours associated with each kilowatt of generating capacity. The cost associated with kilowatt of capacity would be as follows:

Passamaquoddy-Saint John FEDERAL	
Capacity	$19.75
Energy	6.82
Total	$26.57

Thermal (Fossil Fuel) PRIVATE	
Capacity	$27.70
Energy	6.82
Total	$34.52

FEDERAL POWER COMMISSION

ESTIMATED ELECTRIC UTILITY LOADS IN NEW ENGLAND

WEEK OF DECEMBER 7, 1962

EXPANDED TO

ESTIMATED ANNUAL PEAK LOAD IN 1980

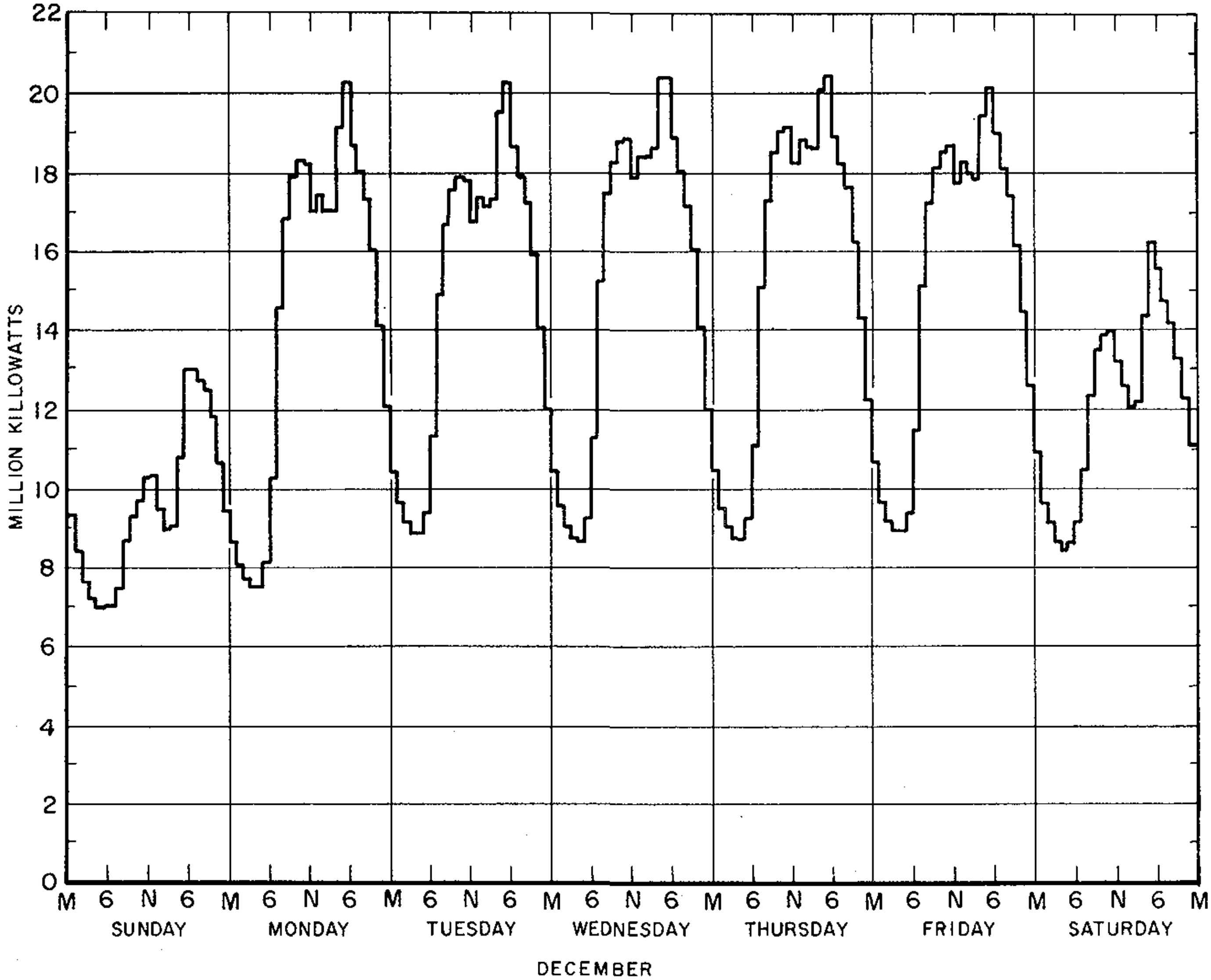


FIGURE 4

Nuclear PRIVATE	
Capacity	$30.89
Energy	4.09
Total	$34.98

Pumped Storage PRIVATE	
Capacity	$30.00
Energy	13.64
Total	$43.64

c. Power Costs

The power studies indicate the following comparison of the cost of peaking capacity from various sources and attest to the marketability of the project's power (2 Hour Peak):

	Federal	Private Financing			
	Quoddy - Dickey	Fossil Fuel	Nuclear	Conventional Pumped Storage	
				Me.	N.H.
Capacity $/Kw	19.75	27.70	30.89	25.32	28.18
Energy	1.56	1.56	0.94	1.66	1.64
	21.31	29.26	31.83	26.98	29.82

d. Marketing Policy

In marketing the electric power generated at the project the Secretary of the Interior shall transmit power and energy to Canada in accordance with agreements reached, and the remaining power will be sold in the United States in such a manner as to encourage the most widespread use thereof at the lowest possible rates consistent with sound business principles. The Secretary of the Interior shall prepare rate schedules having regard to the recovery of the cost of producing and transmitting such electric energy, including the amortization of the capital investment allocated to power, over a reasonable period of years. Preference in the sale of such power and energy shall be given to public bodies and cooperatives.

All moneys received from sales of electric power and energy shall be deposited in the Treasury of the United States as miscellaneous receipts. Downstream benefits provided by the projects and received in the United States from Canadian authorities in the form of power and energy shall be received, transmitted and disposed of by the Secretary of the Interior.

CHAPTER X

POWER COSTS BY ALTERNATIVE MEANS

The Passamaquoddy-Upper Saint John Project is singularly unique in its potential for providing immediate beneficial economic impact and sustained economic benefit for the people of seriously distressed areas of Maine and New Brunswick--areas which compare to any other region in both countries in the roots and consequences of prolonged poverty.

For the first time in history, this imaginative and conclusively demonstrable economic water resource development will provide Canada, the United States, and the World with full-scale generation of electric power from the tides of the ocean. In addition, it will encompass comprehensive development of an important international river in the Northeast, an unparalled international recreational attraction, and significant and continuing new employment opportunities directly and indirectly.

Power, however, is a major feature and function of the project. From this source comes the revenues which must repay the basic cost of natural resource development, as well as the costs of operation, maintenance, replacement, and interest--the requirements of Federal policy and Congressional directive for water resource development.

In order to evaluate properly the value of power from the Passamaquoddy-Upper Saint John Project, a comparison of the cost of power generated by likely alternative sources, in conjunction with due regard for their alternate merits and demerits, must be considered.

The first, and more probable equivalent alternative, would be a modern steam generating plant fired by fossil fuels and operated to provide equivalent power. The cost estimates for such plants, Federal or non-Federal, were furnished by the Federal Power Commission. The economic studies and financial analyses in this report were made on this basis.

Estimates were also made of the cost of generating power from generating plants located in the New England area, with transmission to the Boston area.

Although it was recognized that conventional hydroelectric powerplants, jet engine peaking plants, gas turbine peaking plants, steam topping units or diesel engines are also peaking power sources, the Advisory Board concluded that for the purpose of evaluating power of the magnitude, and characteristic of flexibility and perpetuity of the Passamaquoddy-Dickey Project, it would be sufficient to restrict the comparison to thermal plants, both fossil fuels and nuclear fired, and conventional pumped storage plants.

This decision was made by the Board on the basis that these other alternative sources could not provide peaking power on the magnitude offered by the Passamaquoddy-Saint John River Project, either on a historical basis in New England in case of conventional hydro-e lectric power or by long-term operating experience in the case of other alternatives mentioned above.

a. <u>Thermal Power - Fossil Fuels</u>

The Federal Power Commission furnished the following values for the project's power delivered to load centers in the Maine and Massachusetts areas--the logical markets. These power values include the generating cost, plus the cost of a step-up substation to a high voltage transmission system.

PRIVATE FINANCING

	Massachusetts	Maine
Unit Size - MW	325	100
Capital Cost $/Kw		
Generation	150	180
Step-up Transmission	8	12
Fixed Charges	12.12%	13.42%
Capacity Costs $/Kw	24.78	28.10
Capacity Value Adjustment		
Percent	5	5
Amount	$1.24	$1.41
At-Market Capacity Value $/Kw	26.02	29.51
At-Market Energy Value-Mills/Kwh	2.79	3.31

Composite Value for Area

Capacity - $/Kw	27.70
Energy-Mills/Kwh	3.0

The comparable composite values on Federal financing of a similar modern steam plant are $13.90 per kilowatt for capacity and 3 mills per kilowatthour for energy, based on the current Federal rate of 3% interest.

b. Nuclear Power

The Atomic Energy Commission supplied cost estimates for nuclear powerplants which could provide power roughly equivalent to that which would be generated by the Passamaquoddy-Dickey project. The comparison recognized the fact that nuclear powerplants, as in the case of thermal powerplants using conventional fuels, are essentially base load plants. Thus, when operating as a peaking powerplant such as is envisioned from the Passamaquoddy-Upper Saint John Project, the full economic potential for nuclear energy generation is not realized. However, with this recognition, the capacity and energy costs were furnished by the Atomic Energy Commission for units of 625-MW, 430-MW, and 300-MW capacity using light water reactors. To these costs which are noted on the following table the costs of the step-up substation were added to provide costs at the high voltage bus. Thus, the costs are comparable to the estimates by the Federal Power Commission for fossil fuel plants.

CAPACITY AND ENERGY COST OF NUCLEAR POWER
LIGHT WATER REACTOR

	Private Financing			Federal Financing		
Unit Size	625-Mw	430-Mw	300-Mw	625-Mw	430-Mw	300-Mw
Investment $/KW	130	150	185	130	150	185
			Dollars Per Kilowatt-year			
Annual Capacity Costs						
1. Fixed Charges on Plant	17.6	20.4	25.1	7.0	8.1	10.0
2. Fuel Stock Investment	2.6	2.6	2.7	0.8	0.8	0.8
3. Fixed Operating Cost (Oper., Maint., Adm., and Ins.)	3.4	3.5	3.6	3.4	3.5	3.6
Total Generation	23.6	26.5	31.4	11.2	12.4	14.4
Step-Up Transmission	1.2	1.4	1.5	1.2	1.4	1.5
Total at High Voltage Bus	24.8	27.9	32.9	12.4	13.8	15.9
			Mills Per Kilowatthour			
Variable Operating Costs						
1. Energy Fuel	1.40	1.45	1.50	1.40	1.45	1.50
2. Operation & Maintenance	0.20	0.25	0.30	0.20	0.25	0.30
Total Variable	1.60	2.70	1.80	1.60	1.70	1.80

	Percent
Cost of Money	6.25
Depreciation, 35 yr.S.F.	0.85
Interim Replacement	0.35
Property Insurance	0.40
Taxes (Fed.-3.33-State & Loc. 2.39	5.72
Total	13.57

	Percent
Cost of Money	3.0
Depreciation, 35 yr. S.F.	1.65
Interim Replacement	.35
Property Insurance	.40
Total	5.40

c. Pumped Storage

The Passamaquoddy-Dickey Project contemplates delivery of peaking power to meet a peak of two hours' duration in the Boston, Massachusetts area. Studies were made to determine the cost of providing peaking power in this area by construction of pumped storage plants and the necessary transmission facilities, under both private financing and Federal financing.

The Federal Power Commission supplied information on several pumped storage sites. The Bureau of Reclamation prepared estimates of the cost of pumped storage developments at these sites. The results of the studies are shown on the attached table for the following possible plants:

Rowe Pumped Storage Powerplant (Maine)

This powerplant site is located near Bingham, Maine. It would utilize the Rowe Pond for a forebay and the Kennebec River as an afterbay. The average static head is 775 feet. Installed capacities of 250-MW and 500-MW were considered. Based on 85 percent efficiency, it would be necessary to use 4,500 c.f.s. with a 250-MW plant and 9,000 c.f.s. for a

500-MW plant. To provide for two hours of peaking, 750 acre-feet of storage would be required for the 250-MW plant and 1,500 acre-feet for the 500-MW plant. The cost estimates include the cost of a forebay structure.

Woodstock Pumped Storage Powerplant (New Hampshire)

This pumped storage powerplant would be located near Woodstock, New Hampshire. The information submitted by the Federal Power Commission indicated that this plant would have a head of 960 feet and an installed capacity of 800-MW. Examination of the quadrangle sheet in the vicinity of Elbow Pond indicated that it would not be possible to develop enough storage to provide that head. Estimates were therefore made by proportionately reducing the installed capacity from 800-MW to 670-MW and the ratio of a head of 960 feet to a head of 800 feet. A flow of 11,600 c.f.s. and storage capacity of approximately 2,000 acre-feet would be required to meet a two hour peak. The estimates include a dam on Elbow Pond and a dam on the Pemigewasset River for an afterbay structure. The estimates provide for relocations that would be required in the afterbay structure.

Mt. Tom Pumped Storage Powerplant (Massachusetts)

This site is located on the Connecticut River near Holyoke, Massachusetts. The head on this powerplant is estimated to be 490 feet for an installed capacity of 400-MW. The flow required would be 11,400 c.f.s. and about 1,900 acre-feet of storage would be required to provide two hours of peaking. The cost estimates for this plant include an afterbay structure on the Connecticut River.

Pumped Storage Operation

It must be recognized that pumped storage is an energy-conversion device and not an energy-creating device. It acts much the same as a storage battery. Electric energy must be supplied for pumping water from a lower level to a higher level during periods of excess energy on the transmission system. In fact, it requires three kilowatthours of energy to produce two kilowatthours by pump storage. Thus, power is generated during peaking periods by releasing water through generators from the higher level to the lower level. The operation of pumped storage presupposes a source of low-cost dependable power or self-contained energy for pumping during off-peak periods.

In the case of alternative pumped storage projects in New England and in specific comparison to the Passamaquoddy-Upper Saint John Project, the availability of other sources of low-cost offpeak power or self-contained power is a definite consideration. None of the three alternate pumped storage projects have the advantage of Passamaquoddy's self-contained source of offpeak low-cost dependable power. Furthermore, pumping at this project will be necessary only for very short periods during any given month when minimum tides occur, rather than daily, thus, requiring only nominal amounts of energy.

PUMPED STORAGE

SELECTED SITES IN NEW ENGLAND
RECONNAISSANCE ESTIMATES

SUMMARY

	Rowe (Me.)		Woodstock (N.H.)	Mt. Tom (Mass.)
Installed Capacity	250-MW	500-MW	670-MW	400-MW
Capital Cost $/KW	144	135	150	196

PRIVATE FINANCING

	Rowe 250-MW	Rowe 500-MW	Woodstock	Mt. Tom
Generation $/KW-yr	22.44	21.55	23.28	32.91
Transmission	14.22	9.29	3.70	3.35
TOTAL - $/KW-yr	36.66	30.84	26.98	36.26

FEDERAL FINANCING

	Rowe 250-MW	Rowe 500-MW	Woodstock	Mt. Tom
Generation $/KW-yr	9.74	9.35	9.92	11.79
Transmission	4.87	3.35	1.27	1.00
TOTAL - $/KW-yr	14.61	12.70	11.19	12.79

2 Hour Daily Peak - 5 days per week
Energy assumed to be available at 4.0 mills per kilowatthour

Analysis of Alternatives

Economic analysis alone precludes all privately financed fossil fuel, nuclear, or pumped storage projects as an alternative to the Passamaquoddy-Upper Saint John River Project. In no instance of feasible alternatives can privately financed electric generation provide an equivalent amount of power at a lower cost. The economic alternatives are as follows:

a. Federal Steam Plants. The charges of $13.90 for capacity and 3 mills for energy are less than the equivalent cost for the Passamaquoddy-Upper Saint John River Project. However, no legislative authority exists for the Corps of Engineers or the Department of the Interior to construct or operate conventional steam plants in the continental United States; nor has the Congress elected to adopt such a policy. In any event, this alternative offers no development of regional water resources as specified in Senate Document 97, 87th Congress; nor does it provide any significant area redevelopment or outdoor recreational benefits comparable to the Passamaquoddy-Upper Saint John River Project. And, in the analysis, a Federal Steam plant so operated would be inefficient in providing power such as that available from the Passamaquoddy-Upper Saint John Project.

b. Federal Nuclear Power. A Federally financed and operated nuclear powerplant could again under certain conditions supply power of the same magnitude at a lower cost. However, legislative history provides conclusively that the Congress does not envision wholly-financed and wholly-operated Federal nuclear plants. Furthermore, a Federal nuclear plant would not result in any water resource development, flood control, river regulation, area redevelopment, or outdoor recreational benefits.

Again, as in the case of a Federal steam plant operating on fossil fuels, a Federally owned and operated nuclear powerplant would have to be operated uneconomically to provide equivalent power.

c. Pumped Storage. Federally constructed and operated pumped storage projects could produce equivalent peaking power at a lower cost than the Passamaquoddy-Upper Saint John River Project. Furthermore, under the Flood Control Act of 1944, and under subsequent interpretation and practice, the Federal Government could conceivably construct such projects upon congressional authorization.

This alternative suffers in that none of the three alternate pumped storage sites have a source of dependable low-cost power a vailable from an independent entity nor do they have the capability of self contained power for pumping. Also, a pumped storage project would need outside power daily while Passamaquoddy is dependent upon offpeak generation for pumping for only a few days each month. Nor does pumped storage offer equivalent benefits in water resource development, flood control, river regulation, area redevelopment, and outdoor recreation.

Summary of Alternatives.

None of the three economic alternatives--Federal steam, Federal nuclear, or Federal pumped storage--offers the equivalent in new employment and sustained economic opportunity.

Also, intrinsic in the Passamaquoddy-Upper Saint John River Project is the concept of an international intertie between the United States and Canada in the Northeast whereby the full economic potential of each nation could be fully realized to mutual maximum benefit. Ignoring the other inherent limitations of alternatives, the full development of water resources--a national goal--would be retarded through adoption of other economic alternatives.

There is no alternative to Passamaquoddy to conserve the ever-wasting energy of the tides and putting it to beneficial use.

In the ensuing years, the Department of the Interior is convinced that, in New England, the development of pumped storage, conventional hydroelectric power, modern steam generation, and nuclear plants--whether public or private--will be required. New capital investment by private industry in base-load plants will be absolutely essential.

We are equally convinced that the Passamaquoddy-Upper Saint John River Project is a first and necessary step toward vitally needed economic rejuvenation for people whose ancestors did so much to help frame our national heritage.

SUPPLEMENT TO JULY 1963 REPORT

The International Passamaquoddy TIDAL POWER PROJECT and UPPER SAINT JOHN RIVER Hydroelectric Power Development

Supplementary Engineering Report

CORPS OF ENGINEERS

APRIL 1964

PREPARED BY

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D.C.

IN REPLY REFER TO
ENGCW-PP

13 April 1964

The Honorable Stewart Udall
The Secretary of the Interior

Dear Mr. Secretary:

In compliance with the instructions of the late President Kennedy, as expressed at the White House meeting of 16 July 1963, and in accord with our agreement, I am pleased to transmit herewith my report on the cost and engineering aspects of supplemental studies pertaining to the International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development.

Sincerely yours,

W. K. Wilson, Jr.

W. K. WILSON, JR.
Lieutenant General, USA
Chief of Engineers

1 Incl
Report dtd April 1964

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDED

10 April 1964

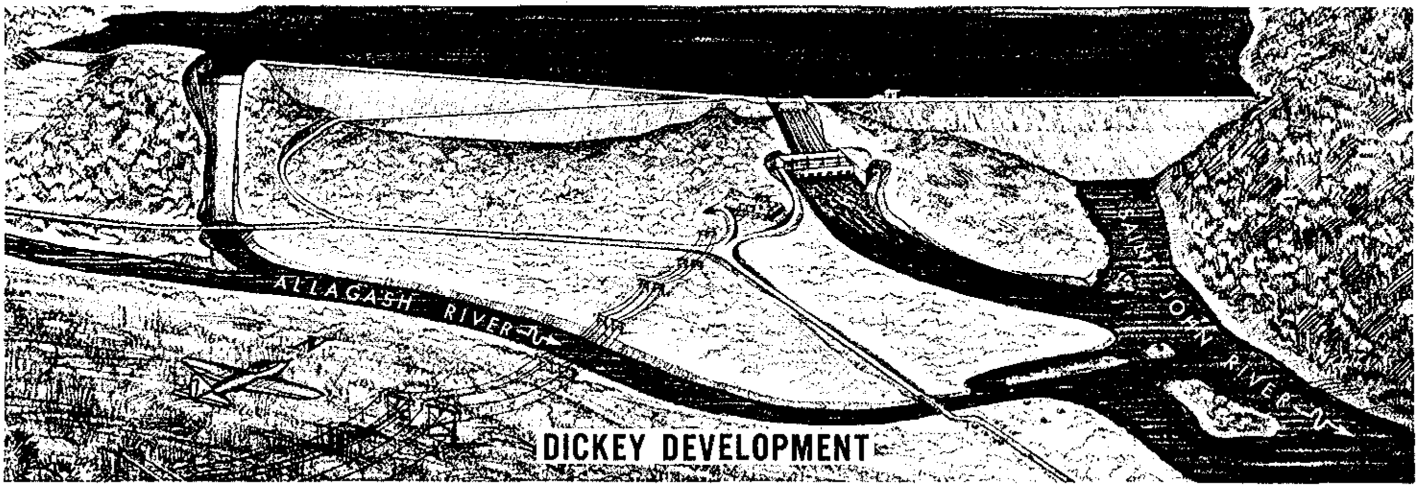
SUBJECT: Transmittal of Supplementary Engineering Report to the Secretary of the Interior's Report Entitled "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Development."

TO: Chief of Engineers
ATTN: ENGCW-E
Washington, D. C.

1. Pursuant to instructions outlined in your letter of 23 July 1963 and in accord with your agreement with the Secretary of the Interior, a supplementary engineering investigation has been undertaken in support of the Secretary of the Interior's report of July 1963 to the late President Kennedy. The investigation covers engineering layouts and cost estimates for various sizes of powerplants with ultimate installed capacity of 1,000,000 kilowatts at Passamaquoddy, Eastport, Maine; and hydroelectric development at Dickey, Maine on the Upper Saint John River with ultimate installed capacity of 760,000 kilowatts and a reregulating dam and powerplant with 34,000 kilowatts installed capacity eleven miles downstream at Lincoln School, Maine. The investigation and report were accomplished with the advice and guidance of the Army-Interior Advisory Board on Passamaquoddy and Upper Saint John River.

2. The supplementary engineering investigation is complete and the report is transmitted herewith.

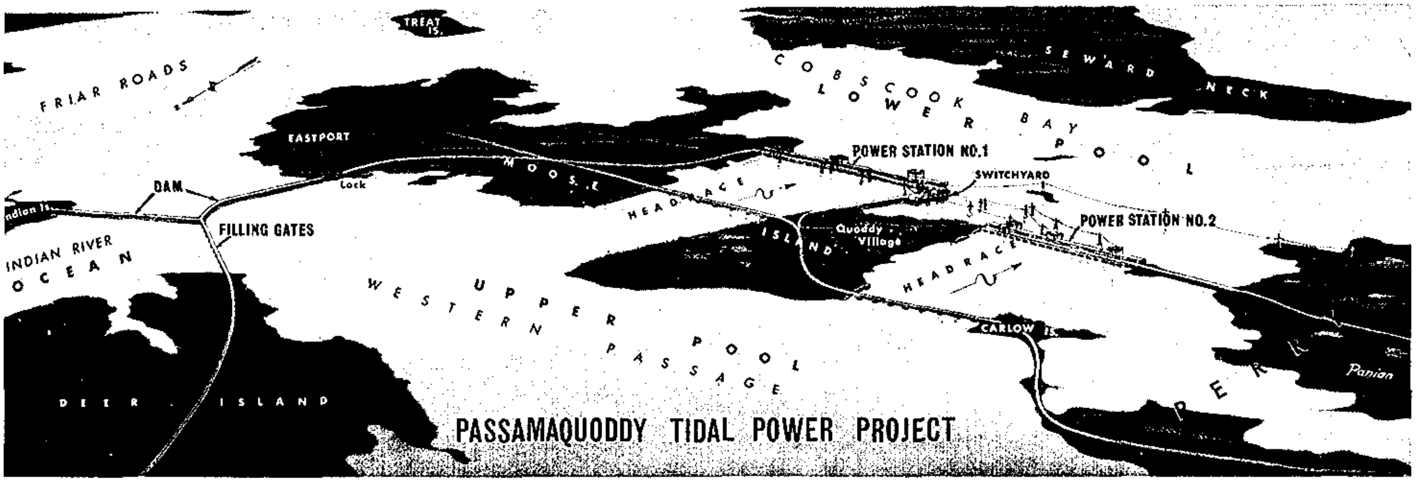
P. C. HYZER
Brigadier General, USA
Division Engineer



SUPPLEMENT TO JULY 1963 REPORT

The International Passamaquoddy TIDAL POWER PROJECT and UPPER SAINT JOHN RIVER Hydroelectric Power Development

ENGINEERING REPORT



SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

ENGINEERING REPORT

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PERTINENT DATA

TIDAL POWER PROJECT

Location

Passamaquoddy Bay and Cobscook Bay, in New Brunswick and Maine.

High Pool

Passamaquoddy Bay, New Brunswick and Maine; Area, sq. mi.	101

Low Pool

Cobscook Bay, Maine, and Friar Roads, New Brunswick; Area, sq. mi.	41

Powerhouse

Two separate 50-unit plants. Powerhouse No. 1 located in Carrying-place Cove, Maine; Powerhouse No. 2 located in Bar Harbor, Maine. Each with fifty 300-inch diameter adjustable-blade, adjustable-gate, propeller-type, inclined-axis turbines, speed 45 r.p.m. connected through a speed increaser to 10,000-k.w., 13,800-volt, 3-phase, 60-cycle generators turning at 450 r.p.m.

Dams

Earth and rockfill type	
Total length, ft.	35,700
Max. height, ft.	315
Crest elevation, ft., m.s.l.	25

Filling and Emptying Gates

Ninety 30- x 30-foot vertical-lift, submerged venturi filling gates. Seventy 30- x 30-foot vertical-lift, submerged venturi emptying gates.

Navigation Locks

Head Harbour Passage, ft.	415 x 60 x 21
Western Passage, ft.	415 x 60 x 21
Little Letite, ft.	95 x 25 x 12
Quoddy Roads, ft.	95 x 25 x 12

Principal Quantities

50-Unit Development (incl. gates and locks)	
Dams - cu. yds.	53,000,000
Cofferdams	
Steel sheeting - tons	62,000
Dikes - cu. yds.	11,000,000
Waste from excavation - cu. yds.	4,500,000
Concrete - cu. yd.	1,700,000
Steel, reinforcing - tons	82,000
Steel, structural - tons	190,000
50-Unit Power Plant No. 2, increment	
Cofferdams	
Steel sheeting - tons	11,000
Dikes - cu. yds.	3,500,000
Waste from excavation - cu. yds.	45,000,000
Concrete - cu. yds.	950,000
Steel, reinforcing - tons	47,000
Steel, structural - tons	10,000

DICKEY PROJECT

Location

Saint John River, Maine, 300 miles above mouth.

Streamflow

Average annual runoff, acre-feet	3,331,000
Maximum discharge, c.f.s.	71,700
Minimum discharge, c.f.s.	129
Average discharge, c.f.s.	4,600

Reservoir

Drainage area, sq. mi.	2,725
Maximum operating level, ft., m.s.l.	910
Limit of drawdown, ft., m.s.l.	870
Usable storage, acre-feet	2,900,000
Total storage, acre-feet	8,080,000
Area, at maximum operating level, acres	88,600

Main Embankment

Crest length, ft.	9,200
Maximum height, ft.	340
Top elevation, ft., m.s.l.	925

Spillway

Crest length, ft.	500
Crest elevation, ft., m.s.l.	910
Design discharge, c.f.s.	50,000

Low Level Outlets

Two 24-foot diameter tunnels controlled by four 90-inch fixed-cone dispersion valves.

Powerhouse

Indoor type, concrete. Eight Francis-type, vertical-axis turbines, average head 293 ft., direct-connected to 95,000 k.w., 13,800-volt, 3-phase, 60-cycle generators turning at 128.6 r.p.m.

Principal Quantities

Rock and earthwork, cu. yd.	65,000,000
Concrete, cu. yd.	500,000
Reinforcing steel, tons	20,000

LINCOLN SCHOOL PROJECT

Location

Saint John River, Maine, 289 miles above mouth.

Streamflow

Average annual runoff, acre-feet	4,981,000
Maximum discharge, c.f.s.	101,000
Minimum discharge, c.f.s.	249
Average discharge, c.f.s.	6,880

Reservoir

Drainage area, sq. mi.	4,086
Maximum operating level, ft., m.s.l.	605
Limit of drawdown, ft., m.s.l.	597
Usable storage, acre-feet	16,000
Total storage, acre-feet	52,500
Area, at maximum operating level, acres	2,200

Main Embankment

Crest length, ft.	1,290
Maximum height, ft.	87
Top elevation, ft., m.s.l.	620

Spillway

Four 30- x 40-foot taintor gates	
Crest elevation, ft., m.s.l.	575
Design discharge, c.f.s.	92,500

Powerhouse

Indoor type, concrete. Two Kaplan-type vertical-axis turbines, average head 61 feet, direct connected to 17,000-k.w., 13,800-volt, 3-phase, 60-cycle generators turning at 138.5 r.p.m.

Principal Quantities

Rock and earthwork, cu. yd.	2,200,000
Concrete, cu. yd.	85,000
Reinforcing steel, tons	4,000

CHAPTER I

INTRODUCTION

1-01 AUTHORITY

At Eastport, Maine, the large tidal range has long intrigued observers as a natural resource that could be used for the development of electric power. There are two large natural tidal bays that are connected by water passages between a string of islands which stand between the bays and the open ocean. Passamaquoddy Bay, the larger of the two, is mainly located across the international boundary in Canada while Cobscook Bay lies entirely in the United States. By connecting the islands with a series of dams in designed pattern separate tidal pools can be formed and water elevations regulated to maintain the pools at different levels. If a powerhouse is placed between the two pools and water permitted to pass from the higher to the lower the induced head differential will produce power.

The development of tidal power at Passamaquoddy has been studied periodically since 1919 by both private and public engineers. The most comprehensive report undertaken was that of the International Joint Commission completed in April 1961 after three years of study and a cost of three million dollars. The project was developed as a two pool scheme interconnected with a powerplant that would operate continuously but with varying output. The powerhouse was a 30-unit plant with vertical axis turbine and generator units with a capacity of 10,000 kilowatts each. The Commission found the project not economically feasible under the then existing conditions.

In early July 1963, as a result of an earlier request to review the I.J.C. report to ascertain whether developments in engineering techniques and/or economic conditions would make the project feasible, the Secretary of the Interior presented to President John F. Kennedy a report on "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development." This report proposes to use the power output to meet the demand for peak power in the New England area, and when coupled with the advancement in engineering techniques and integrated with a hydroelectric plant on the Upper Saint John River would make the project economically feasible. The same structures were used for the tidal project, except for the powerhouse where an inclined axis turbine was substituted for the more conventional vertical axis turbine. From the studies made of power potential, it was proposed that an ultimate installation of 100-10,000 kilowatt units could be installed at Passamaquoddy. Integration with another source of power is necessary since tidal output varies with the tide range, a minimum occurring about every two weeks at periods of neap tides when the available head is lowest. In order to supplement and maintain power output at these periods an auxiliary hydroelectric plant with an ultimate capacity of 750,000 kilowatts would be established on the Saint John River at Dickey. The Dickey Dam site was selected by the Department of the Interior in lieu of the Rankin Rapids project considered by the I.J.C. in order to preserve the recreational values of the Allagash River. Integrated operation of the two plants would assure dependable peaking capacity of the planned magnitude of 1,000,000 kilowatts and 250,000 kilowatts capacity at 60 percent load factor for energy output.

On 16 July 1963, the President directed the Departments of the Interior and Army to proceed immediately with such additional studies and plans as are necessary and that the studies be coordinated in all respects by the Secretary of the Interior. Pursuant to this general understanding, Lieutenant General W. K. Wilson, Jr., the Chief of Engineers, by letter of 29 July 1963, proposed an eight-member Army-Interior Advisory Board on Passamaquoddy and Upper Saint John River, with four representatives from each agency. The purpose of the Board is to advise and guide both field agencies in their preparation of additional studies, plans and reports to supplement the July 1963 report to the President by the Secretary of the Interior on the International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development. By letter of 30 July 1963, Mr. Kenneth Holum, Assistant Secretary, Department of the Interior, agreed to this procedure. The Board was later increased to fourteen members by adding representatives from the Federal Power Commission, Department of Commerce, Bureau of Budget, Office of Science and Technology, Council of Economic Advisors, and the Atomic Energy Commission. Membership of the Board is given in Appendix I.

1-02 SCOPE OF ENGINEERING STUDIES

The division of work between the Corps of Engineers and the Department of the Interior, as indicated by the initial agreement between the agencies and confirmed by the Advisory Board, was to the effect that power studies, power transmission, marketing, benefits, and other economic aspects of the project would be the responsibility of the Department of the Interior and that the development of the physical components, other than transmission lines, would be the responsibility of the Corps. The detailed engineering studies and requisite field work were to be performed by the Division Engineer, New England Division, Waltham, Massachusetts.

The studies undertaken for this report to attest to the engineering feasibility and soundness of the engineering structures of this project were as follows:

a. Geologic investigations and field explorations at the sites of all structural components.

b. Field surveys.

c. Hydrologic investigations of the Saint John River.

d. Layout and design of facilities for powerplants at Passamaquoddy; power dam and closure dikes at Dickey; and reregulating and power dam at Lincoln School.

e. Studies of use of inclined axis turbines at Passamaquoddy in cooperation with the Bureau of Reclamation.

f. Planning appraisal of all lands and damages for the entire project.

g. Cost estimates of facilities, except transmission facilities.

The layouts of the construction proposed and the cost estimates for the entire project are presented in the following chapters.

CHAPTER II

SITE INVESTIGATIONS AND FOUNDATION CONDITIONS

PASSAMAQUODDY

2-01 GENERAL GEOLOGY

Bedrock of the project area includes sedimentary and igneous rocks of upper Silurian age known as the Eastport Formation. The sedimentaries are shales and conglomerates and the igneous rocks are represented by rhyolitic and diabasic varieties and associated volcanic tuffs. These rocks have been much folded to present a complex distribution of alternating beds of igneous and sedimentary rocks.

Prior to glaciation, the bedrock topography was subjected to a long period of erosion featured by development of deep-stream valleys. The land was greatly depressed by the advance of thick glacial ice in Pleistocene time, and with retreat of the ice came invasion by the sea. Since glaciation, full emergence has not been attained and the pre-glacial stream valleys are partly drowned to form the deep marine channels, while the numerous islands are high areas of the old erosional surface.

The pre-glacial topography was slightly modified by movement of the ice mass in the removal of the weathering mantle and in the plucking and smoothing of the rock surface. More pronounced modification resulted from deposition of rock debris carried in and on the ice. Materials that were deposited directly from the ice generally occur as a veneer over the rock surface in the form of glacial till, a compact mass mixture of all sizes of rock and earth materials. Coarse materials that were outwashed from the ice occur as remnant deposits of sorted sands and gravels. The fine materials that were outwashed to settle in quiet waters of the invading sea occur as thick deposits of marine clay and silt. Since glacial time, the outwash deposits exposed to sea attack have been reworked by waves and transported by currents to form bars and beaches. Minor deposition by streams has occurred and peat has locally accumulated in bogs and marshes.

2-02 EXPLORATIONS

Investigations previously made over a number of years for Powerhouse No. 1 and channels are sufficiently complete as to preclude need for further exploratory work. These investigations, which include concrete aggregate studies applicable to Powerhouse No. 2, are detailed in *Report to the International Joint Commission*, 1959, Appendix 2 - Geology, Foundations and Materials.

Previous subsurface explorations pertinent to the areas of Powerhouse No. 2 and channels have consisted of the following:

a. Eight (8) scattered wash borings indicating elevation of bedrock made for the Cooper Study of 1926-28.

b. Three (3) drive-sample and core borings made by the Corps of Engineers in 1935 on alignments of the Carlow Island and Pleasant Point Dams.

c. Marine geophysical exploration extending into a portion of the tailrace channel in the vicinity of Spectacle Island, cooperatively made on a trial basis in 1951 by the Corps of Engineers and U. S. Geological Survey.

Current explorations made for the purpose of this report, specifically for Powerhouse No. 2, included geological reconnaissance on land and water and the drilling of two test borings recovering 2-inch drive samples and 2-1/8-inch diamater rock cores made to investigate foundation and excavation conditions for the powerhouse structure. Boring FD-1 was drilled and hydraulically pressure-tested in rock to elevation minus 89.0 m.s.l. or slightly below maximum required depth of structure excavation. Although this boring is located off the structure because of subsequent adjustment in layout, the conditions encountered are considered pertinent. Boring FD-2, which was made to establish depth to bedrock on the west end of the original layout for the powerhouse, is now located nearly 1,000 feet southwest where it becomes more applicable to excavation conditions in the tailrace channel. Other explorations consisted of 29 machine-driven probings to preliminarily determine division of earth and rock materials to be excavated in the headrace and tailrace channels. These probings were distributed in water areas of the channels lacking in surficial and subsurface data and were driven to below proposed grades or to refusals above grades.

The locations and records of previous and current explorations and the distribution of bedrock exposures for Powerhouse No. 2 are shown on Plate No. 4 entitled "Plan and Record of Explorations."

2-03 STRUCTURE EXCAVATIONS AND FOUNDATIONS, POWERHOUSE NO. 2

Ground elevations will vary from a few feet to nearly 60 feet above mean sea level on the powerhouse alignment. Structure excavation will amount to over two million cubic yards, principally rock, and deepest excavation will be about 140 feet in reaching lowest invert of about 80 feet below m.s.l.

Overburden excavation will vary from a skimming to an estimated maximum depth of 30 feet to reach the rock surface. Overburden is principally glacial till with the major exception of the marsh area along about the southeasterly third of alignment where marine clay attains a thickness of 15 or more feet.

Reconnaissance geologic mapping and the rock cores recovered from boring FD-1 indicate that rock excavations will principally encounter igneous rocks, rhyolite and diabase in flows, sills and dikes with subordinate occurrences of sedimentary rock (shale) and tuffs (cemented volcanic fragments). These rocks singly or in their various complex associations present no apparent problems as to their competency for bearing heavy foundation loads. However, the many contacts of rock types, occasional fault zones and the presence of numerous open and healed fractures and cracks may relate to problems of water pressures and inflows requiring grouting during and after excavation, and to difficulties in producing any close tolerances that may be required for precise or shaped excavations. The fractured condition of the rock as recovered in cores from the deep Test Boring FD-1 is pictured on Figure 1, and a graphic record of tests for hole leakage using water under pressure is shown on Plate No. 4. These tests indicate openness in some zones by flows of up to 16 gallons per minute under maintained pressures of 20 to 50 p.s.i.

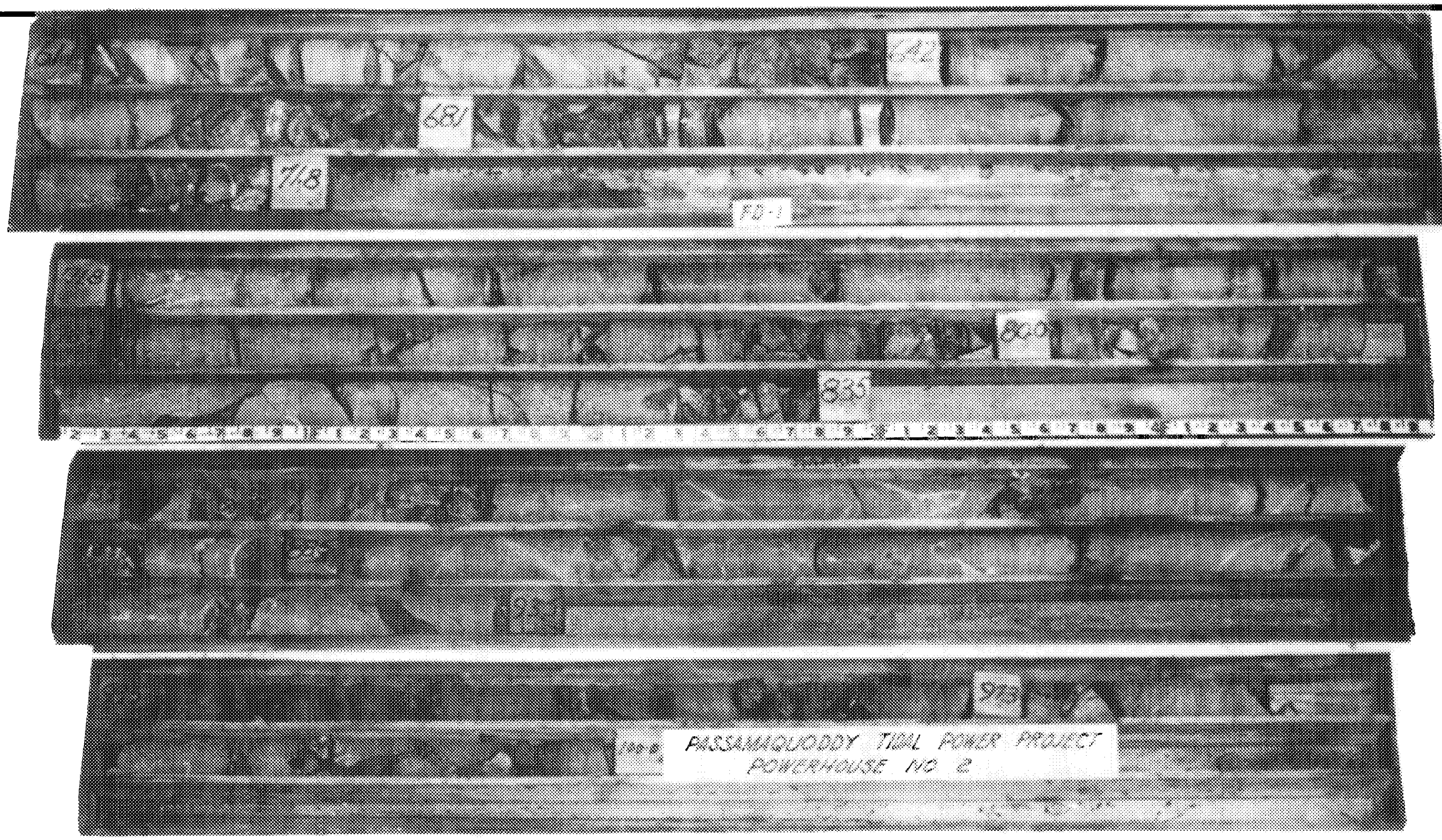
2-04 CHANNEL EXCAVATIONS

Excavations for the headrace and tailrace channels will involve over 50 million cubic yards with a greater proportion in the headrace channel where grade is constant at -40.7 m.s.l. Deepest excavation, to -67.0 mean sea level and mainly in rock, will occur in the beginning of the tailrace channel near the southerly shore of Moose Island.

Overburden of the land and islands and their fringes is glacial till, except for localized marsh areas and clay deposits. The overburden of the water areas is clay overlying the till which veneers the rock surface.

All of the igneous and sedimentary rock types previously discussed will be encountered. From available surficial and subsurface geologic data, it is preliminarily estimated that 50 percent of channel excavations will involve rock.

FIGURE 1



PASSAMAQUODDY TIDAL POWER PROJECT
POWERHOUSE NO. 2
BORING FD-1, BEDROCK CORES BELOW DEPTH OF 61.1' (ELEV.-50.1)

2-05 TIDAL DAM

A low tidal dam would connect from the powerhouse westerly across Bar Harbor to the Perry mainland. The elevation of bottom near mid-channel is about -30 m.s.l. making maximum height of embankment about 50 feet. A single machine-driven probing near this point shows about 4 feet of soft material, followed by increasing resistance to penetration and a refusal indicative of bedrock at -38.3 m.s.l. Materials required for embankment construction amount to approximately 400,000 cubic yards and perhaps except for special gravel requirements can be selectively obtained from required excavations for powerhouse and channels.

DICKEY DEVELOPMENT

2-06 GENERAL GEOLOGY

The wilderness area which comprises much of the Upper St. John River basin in the United States, was not mapped topographically until 1953. Geologic mapping has been only of limited reconnaissance scope except for the published detailed investigations in the igneous rock area at Deboullie Mountain. In the Canadian part of the upper basin, detailed geologic mapping of correlative value is available for the area bordering the St. Francis River in Quebec.

The upper St. John River basin is a maturely dissected upland region which has been modified by glaciation. The headwaters area is predominantly a region of low relief with wide, flat plains, mostly swamps, and low, broadly domed hills with occasional, widely scattered monadnocks. Downstream from the headwaters of the reservoir along the main river and throughout the Allagash and Little Black River drainage areas, the relief is greater and the topography is rougher with steep hills and narrow-crested, broken ridges rising above generally narrow, trough-like valleys. Till consisting of variable, gravelly, silty to clayey sand with cobbles and boulders, deposited by the last glacier blankets the bedrock throughout most of the region. The till is generally thin on the upper slopes and crests of the hills and in these areas bedrock is occasionally exposed. The valley bottom and lower hillsides are generally deeply filled with till and outwash left by the wasting glacier. The outwash deposits composed of variable, roughly stratified, silty sands and gravels occur in thick outwash plains in the valley bottoms and extensive terraces on the lower valley walls. Because the St. John River drains northward, it was dammed at successive locations against the retreating ice front. In the sluggish pools thus formed, thick deposits of laminated fine sand, silt and clay were laid down. As a consequence of the thick filling in the valley bottoms, the rivers now flow high above the deep pre-glacial valleys in bedrock, and rock is exposed only in uncovered bedrock spurs high on the old valley walls.

Bedrock throughout the basin consists of slaty shale with local thin beds of sandstone and limestone. These Silurian sediments have been folded so that original bedding is largely obscured and slaty cleavage has developed sufficiently so that the shale in many areas grades to poor slate. The only major occurrence of igneous rocks in the upper basin is the syenite and granodiorite in the vicinity of Deboullie Mountain.

No occurrences of mineral deposits of economic value have been reported in the upper basin.

2-07 EXPLORATIONS

At the initiation of work on the Dickey project, reports of all previous investigations on the upper St. John River were reviewed. The review included study of reports of sites at Lincoln School, Rankin Rapids, Cross Rock Rapids and Big Rapids. Reports of investigations by Canadian agencies at Glazier Lake on the St. Francis River were also reviewed. Field investigations were made initially for a designated dam alignment immediately downstream from the Dickey highway bridge. At this location, hereafter discussed as the upper site, explorations consisted of a total of 11 borings including 3 borings made for the Dickey highway bridge by the Maine State Highway Commission in 1950. Unfavorable foundation conditions developed by these explorations led to investigation of an indicated more favorable site approximately 1-1/2-miles downstream and just above the mouth of the Allagash River. Seven (7) borings were completed at this site for preliminary exploration of foundation conditions. The locations of explorations and bedrock outcrops at both sites are shown on Plan of Exploration, Plate No. 11. Foundation conditions at the Fall Brook dike site were explored by 3 borings, and 1 boring was completed at the Hafey Brook dike site. Subsurface explorations were not made at the Campbell Brook dike site or at the very remote minor dike sites.

Field surveys were made to obtain baseline profiles and to establish boring locations at the upper and lower Dickey sites and at the Falls Brook and Hafey Brook dike sites. All borings were drive-sampled in overburden, and the bedrock, where encountered, was drilled with coring diamond bits. The classification of overburden samples and description of bedrock cores recovered from borings at the selected downstream damsite and the Falls Brook and Hafey Brook dike sites are shown on Record of Explorations, Plate No. 14.

2-08 SITE SELECTION

Explorations indicated that subsurface conditions encountered at the upper site were not favorable for construction of a high dam. As shown on Geologic Section, Plate No. 13, the very thick deposits of soft silt and clay which occur throughout the valley bottom, would necessitate very flat slopes on the dam, and the relatively pervious materials which occur to depths of more than 40 feet would require a deep cutoff and elaborate downstream drainage. The very thick, relatively pervious materials in the left abutment extend to depths of more than 150 feet below the valley bottom, making cutoff impractical and control of seepage very difficult. Because bedrock is inaccessible in the left abutment and valley bottom, it would be necessary to concentrate the diversion tunnels, penstocks, powerhouse and spillway in a relatively limited area of the right abutment.

It was found by reconnaissance, which continued during the exploration of the upper site, that at a lower site bedrock outcrops occurred on the top and upper slopes of the prominent hill immediately above the mouth of the Allagash River and at other locations along the Allagash River bank and the south side of the valley as shown on Plan of Exploration, Plate No. 11. On the north side of the valley, a gully was found which formed a deep reentrant in the continuous pervious terrace deposits so that cutoff to till is possible. In view of the feasibility of cutoff in the left abutment and the availability of bedrock for structure foundations at several locations, a dam alignment at this location, the lower Dickey site, was finally selected. This selected site is hereinafter designated as the Dickey damsite.

2-09 FOUNDATION CONDITIONS

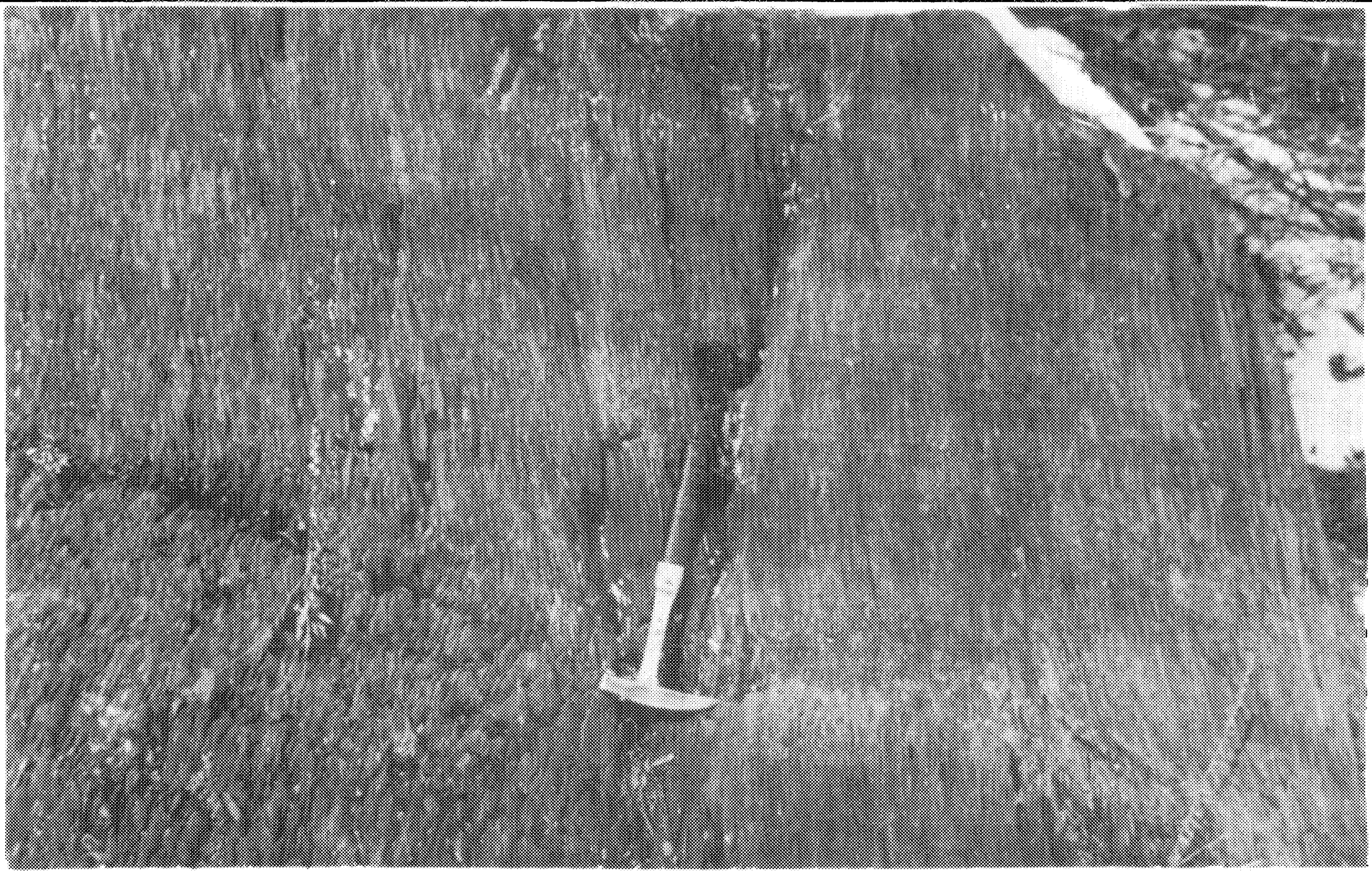
a. Dickey Dam. In the valley bottom below the nominal channel deposits of silty, sandy gravel, outwash consisting of silty sand, sandy and clayey silt extends to a depth of approximately 40 feet as shown on Geologic Section, Plate No. 13. Cutoff through the river channel deposits and into the upper part of the relatively impervious outwash materials is possible at reasonably shallow depths.

Beneath the fine outwash a zone of stratified silty sands and gravels with scattered till lenses approximately 50 feet thick overlies the basal till which extends to bedrock in the bottom of the valley at depths of more than 180 feet below the river. The fine outwash deposits in the valley bottom extend up the left abutment in a deep gully to a height of more than 100 feet above the river, but throughout the gully area the outwash is blanketed by up to 40 feet of till. Upstream and downstream adjacent to the gully the prominent terraces on the abutment form very thick deposits of silty sands and gravels with beds of sandy silt and zones of till. Above the terraces the upper slopes of the abutment are blanketed with till. The fine-grained outwash which occurs in the valley bottom also extends up the right abutment of the river section to heights above the highway, but again these materials are blanketed by till with thin beds of sand and gravel so that cutoff to relatively impervious material is available at reasonable depths. Throughout the upper slopes of the right abutment the till extends to bedrock at depths estimated at about 30 feet.

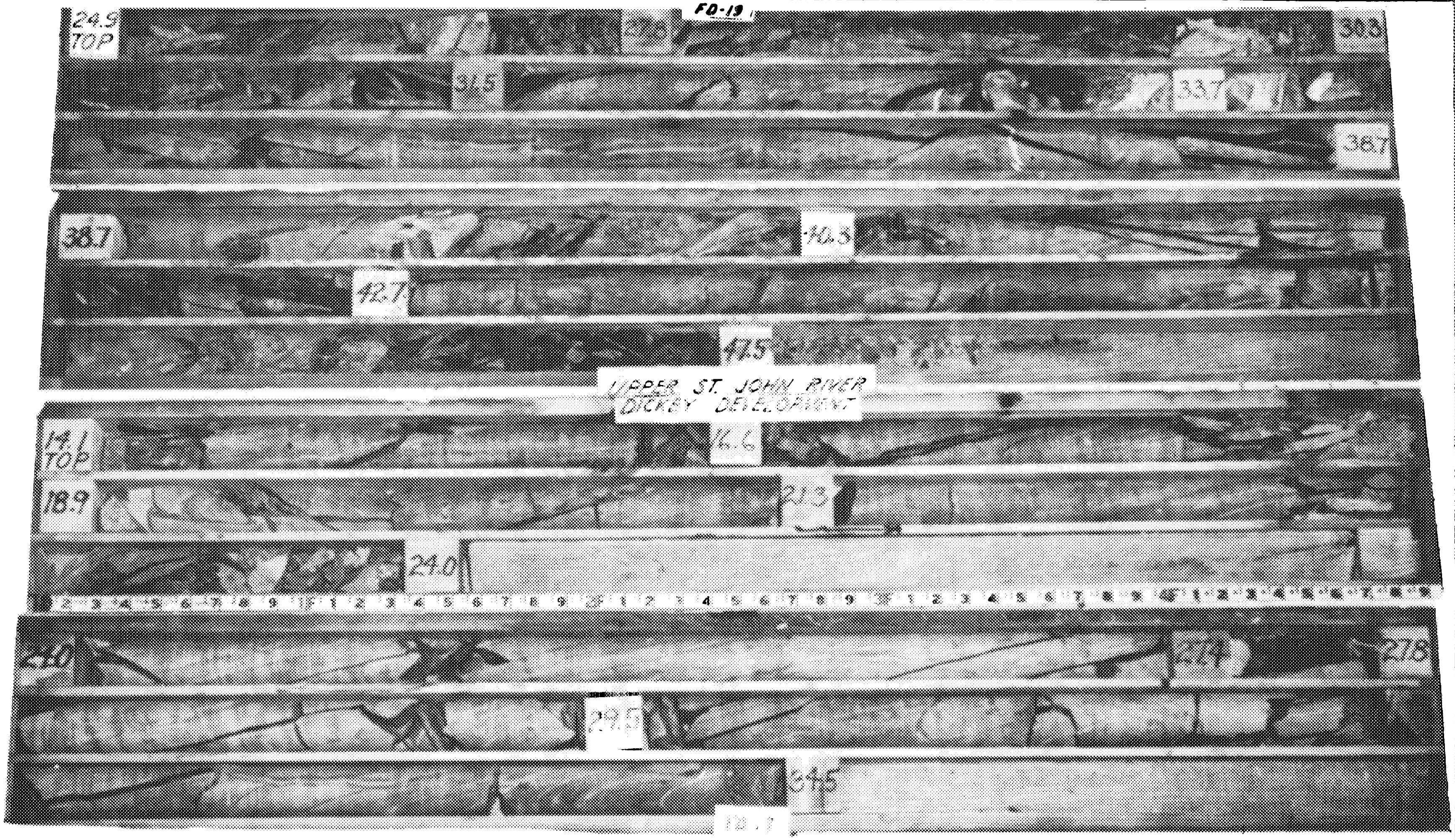
On both abutments at the south section of the dam, the overburden is generally thin and consists of till composed of gravelly, silty sand. Along the lower part of the left abutment, as shown on Geologic Section, Plate No. 13, it is expected that the thickness of the till cover increases to 40 feet or more and grades into a more silty, clay till. The bottom of the broad, flat valley is largely a peat bog with organic deposits estimated to be about 10 feet in thickness. Underlying the organic material, stratified, silty sands and gravels occur to estimated depths of 60 feet to 75 feet. Cutoff through these relatively pervious outwash materials can be made to the underlying till which extends to bedrock. Although some fine-grained soils occur in the foundation, they appear to be dense and have relatively high shear strengths and would permit relatively steep design slopes for the embankment.

The bedrock is dark gray to black, relatively hard, slaty shale, generally calcareous and locally graphitic. Thin sandstone beds and occasional quartz stringers occur in the shale at widely scattered localities. The trend of the conspicuous cleavage is North 40° to 50° East. The dip of the cleavage ranges from vertical to 70° West. The photograph on Figure 2 shows a typical outcrop of the shale. Although the shale is generally hard, weathering has commonly progressed along numerous open cleavage planes and joints to depths of more than 10 feet and locally to more than 20 feet. In Boring FD-16 located at the intake area for the conduit tunnels, a thin zone of fault breccia was encountered at a depth of 17.1 feet below the rock surface. Photographs of representative bedrock cores from borings are shown on Figure 3. Physical tests performed by others on similar rock from damsites on the Canadian side of the St. John River show a specific gravity

FIGURE 2



DICKEY DEVELOPMENT
DICKEY DAM
SHALE OUTCROP SHOWING TYPICAL SLATY CLEAVAGE



DICKEY DEVELOPMENT
DICKEY DAM
BEDROCK CORES FROM BORINGS FD-17 AND FD-19

FIGURE 3

range of from 2.73 to 2.79 and compressive strengths for saturated samples ranging from 8,330 psi to 10,380 psi.

Slaking tests performed on samples of similar slaty shale from the Rankin Rapids damsite showed no significant breakdown during 34 cycles of wetting and drying.

The alignment of structure excavations, spillway and tailrace channels and diversion tunnels is nearly normal to the trend of the bedrock structure. This favorable relationship of excavations to the attitude of the rock structure will assist materially in producing stable side slopes in open rock excavations and will minimize overbreak in both open excavations and in the diversion tunnels. Below the upper weathered zone the structure of the rock makes it generally adaptable to application of line drilling or presplitting where vertical slopes are required for structure excavations. In required excavations, some of which are up to 150 feet in depth, where structures are not involved, it may also prove to be economical to produce vertical slopes rather than conventional 4 on 1 slopes depending on refined estimates of rock quantities required from excavations.

Bedrock is generally sufficiently deeply buried and blanketed with thick deposits of relatively impervious till so that only a minor grouting program will be required. Provision for grouting is advisable in the cutoff near the penstock intake structure and in the vicinity of the spillway. Because of the relatively low heads occurring at these high elevations, only shallow grouting would be required. On the abutments of the south section of the dam where bedrock is exposed or close to the ground surface, deeper grouting will be done as necessary to provide adequate cut-off. In view of the character and condition of the bedrock, it is expected that the quantity of grout "take" will be nominal.

b. Falls Brook Dike. At the Falls Brook dike site which is the major remote dike, the overburden on the abutments is till as shown on Geologic Section, Plate No. 13. On the left abutment the till cover is very thin near the bedrock outcrops high on the slope. On the upper slope of the right abutment, the till is also thin, but the thickness of the till blanket increases down the abutments to the deeply filled valley bottom, where the till rests on bedrock at depths of more than 90 feet. In the valley bottom the till is covered by outwash consisting of silty sands and gravels with minor lenses of till. The outwash is generally less than 10 feet thick, although local accumulations up to 25 feet occur. Cut-off through the relatively pervious outwash deposits to the till is therefore possible at generally shallow depths. The bedrock is the common slaty shale with characteristics similar to the rock at the damsite.

c. Hafey Brook Dike. At Hafey Brook Dike site the overburden on the right or east abutment is till generally about 10 feet in thickness as shown by boring FD-10. Although subsurface information is not available in the valley bottom or west abutment, reconnaissance indicates that it is quite possible for a deeply filled valley in the bedrock to occur in this area. Immediately north of the dike site there is an extensive outwash plain floored with sands and gravels. If a deep buried valley does occur at the site, it is probably filled with similar sands and gravels.

Bedrock encountered in the boring at the site is andesite with scattered quartz stringers and shale inclusions. The bedrock exposed in extensive outcrops immediately south of the site is slaty shale.

d. Campbell Brook Dike. The overburden on the abutments at Campbell Brook dike is till. It is assumed that the organic materials, probably superficial in depth which occur in the valley bottom, are underlain by thin deposits of sand and gravel resting on till.

Bedrock was not found outcropping in the vicinity of the site. Outcrops on the valley wall south of the site, however, indicate that the bedrock is the regional slaty shale.

e. Blue Brook Dike and Cunliffe Brook Dike. These remote minor dike sites have not been visited. It is assumed, however, that the overburden on the abutments at these locations is till. Superficial organic deposits probably occur in the valley bottoms overlying till. Bedrock at the sites is assumed to be the regional slaty shale.

2-10 EMBANKMENT AND FOUNDATION DESIGNS

a. Dickey Dam. Typical sections of the embankment for Dickey Dam, designed for maximum utilization of available materials, are shown on Plate No. 7. The section design provides for a minimum core section composed of glacial till, flanked by large relatively pervious zones. The large pervious zones not only enables full utilization of the more economically available earth borrow, but permits earth placement to be carried out over a longer construction season than possible with moisture sensitive materials. Also the internal design can be modified considerably in final design to suit the characteristics of materials actually available and adopted construction sequences without change in outer slopes. Seepage through the embankment is controlled by the arrangement of the impervious and pervious fill zones, and foundation seepage is, in general, controlled by carrying the impervious section of the dam to rock, glacial till, or other impervious stratum. At the left abutment, however, it may not be feasible to obtain complete foundation cutoff, and the cost estimate provides for inclusion of a short upstream impervious blanket and a drainage tunnel downstream for intercepting possible underseepage at this abutment.

Because of the slaty nature of rock from required excavations, and the need for processing to remove the expected large quantity of excess fines, rock slope protection is provided only on the upstream slopes. Below minimum pool, the rock slope protection will consist of processed rock from required excavation and a select granitic rock transported from the Deboullie Mountain area will be used above. Downstream slopes will be protected by gravel and cobbles from the pervious borrow and site excavations.

b. Falls Brook Dike. The only known sources of large quantities of embankment materials in the vicinity of the dike site appear to be deposits of relatively impervious glacial till. This dike has therefore been designed as an essentially homogeneous impervious fill section, with impervious cutoff carried through shallow pervious deposits to rock or impervious glacial till. An internal pervious wick drain and downstream horizontal pervious blanket are provided for controlling through and under seepage. Slope protection on the upstream slope above the minimum pool will consist of select granitic rock from the Deboullie Mountain area and processed gravel below. The downstream slope protection will consist of locally quarried rock.

c. Hafey Brock Dike. Materials indicated to be available in the area for embankment construction are pervious sands and gravels and impervious glacial till. Cutoff to bedrock or other impervious stratum does not appear feasible in the valley bottom and at the west abutment. A horizontal upstream impervious blanket connected to the core, a pervious fill drainage trench downstream of the core, and a downstream rock toe are provided for control of seepage. However, the upstream impervious blanket is eliminated where cutoff to rock or glacial till appears feasible on the east abutment. Upstream slope protection will consist of select granitic rock from the Deboullie Mountain area above minimum pool and processed gravel below. The downstream slope protection will consist of locally quarried rock on gravel bedding.

d. Campbell Brook, Cunliffe Brook and Blue Brook Dikes. These dikes which are of relatively low height are designed as essentially homogeneous impervious fill sections, utilizing the local glacial till, with pervious downstream toes, for control of seepage. Cutoff to impervious glacial till is assumed at relatively shallow depth. Upstream slope protection for the Campbell Brook Dike will consist of select granitic rock from the Deboullie Mountain area. Downstream protection will consist of processed rock from required excavations at Dickey Dam. Local rock will be used for all slope protection at Cunliffe Brook and Blue Brook Dikes.

2-11 CONSTRUCTION MATERIALS

a. General. Quantity estimates of borrow materials required for construction of the dam and dikes are based on available topography and geology for the various sites and preliminary designs appropriate to this stage of investigations. Estimated volume of the main dam and dike at Dickey including rock slope protection and rockfill is approximately 56,000,000 cubic yards. The volume of earth and rock materials in the Falls Brook dike is about 7,300,000 cubic yards. At Hafey Brook dike approximately 2,000,000 cubic yards of earthfill and rock are required. The minor dikes have small volumes ranging from 40,000 to 200,000 cubic yards.

b. Impervious Materials. Foundation test borings made high on the left abutments at both the sites investigated at Dickey indicate that thick and extensive deposits of till occur generally above Elevation 900. The till is compact, relatively impervious and characteristically variable. It contains scattered boulders and ranges in gradation from gravelly, silty sand to gravelly, sandy clay. Preliminary estimates indicate that an area extending upstream along the valley 2 miles or more from Dickey damsite could provide all impervious materials required for the impervious sections of the dam. Other localities where extensive deposits of relatively impervious till occur within 2-1/2 miles of the site include the high slopes on the north valley wall downstream from the site and the higher hillside on the south side of the valley between the upper and lower Dickey sites.

At the Falls Brook dike impervious materials are available in nearby extensive till deposits on the east side of the Falls Brook Valley both upstream and downstream from the site. Sources of impervious materials for the other dikes were not specifically located. However, it is expected that deposits of till suitable for use as impervious fill can be found in proximity to all the sites.

c. Pervious Materials. Pervious materials for construction of the Dickey Dam occur in extensive terrace deposits of silty sands and gravels which extend from river level to about Elevation 800 along the north side of the valley. In some areas the terrace materials are mantled by till. Within these deposits, till also occurs in scattered small masses and thin lenses. The total thickness of the pervious materials, including the relatively minor till zones, is generally more than 100 feet. It is expected that adequate exploration of these deposits would permit delineation of suitable areas where it would be feasible to obtain very large quantities of relatively pervious material. Without some selection, these deposits would probably provide material which overall would be classified as random fill.

Foundation explorations for the southern section of the dam at the lower Dickey site and in the valley bottom at the upper site encountered more than 40 feet of relatively pervious silty sands and gravels, and similar materials occur in the extensive outwash plain at the mouth of the Little Black River. The water table is generally less than 20 feet deep in these areas so that subaqueous borrow operations would be required to realize more than a nominal percentage of an indicated large potential.

Other potential sources of pervious borrow occur in a large terrace approximately 11 miles downstream from the Dickey site and in less extensive terraces on the east side of the Allagash River from Three Mile Island to Twin Brook Rapids about 4 miles from the Dickey site.

A nearby source of pervious materials has not been found in the vicinity of Falls Brook dike. For purposes of this report it is assumed that pervious materials will be obtained from deposits in the vicinity of the damsite.

Immediately north of the Hafey Brook dike site, there is an extensive outwash plain indicated to be underlain by gravelly sands in sufficient quantity for pervious fill requirements.

At Campbell Brook dike all pervious materials required will be obtained from pervious deposits at Dickey. At Blue Brook and Cunliffe Brook dike requirements for pervious fill have been kept to a minimum in preliminary designs and it is assumed that they can be found within 5 miles haul distance of the sites.

d. Gravel Bedding, Slope Protection and Road Gravel. It might be possible to obtain these materials by selective excavations in the areas considered as potential sources for pervious material. Considering the large quantities required, however, it is believed more realistic at this time to assume that all gravel for bedding, slope protection and roads will be obtained by processing materials from the most suitable pervious borrow areas. Campbell Brook dike is only a short haul distance from the Dickey site and could be supplied from a processing plant at Dickey. Select gravel materials for the dikes at Falls Brook and Hafey Brook likewise could probably be supplied most readily from a central processing plant located at Dickey.

e. Rock Slope Protection and Rockfill. The slaty shale bedrock will provide most of the required rock for slope protection and rockfills. The shale bedrock from the required rock excavations will be utilized at the dam and adjacent dike. At the remote dikes most of the required slope protection or rockfill will be provided by quarrying in nearby areas.

Cleavage is very well developed in the shale so that it will split easily into thin plates and wafers, and shapes produced by blasting will be elongate, flat slabs. Breakdown of the rock during blasting and handling will result in production of a high proportion of undesirable fines. Processing will, therefore, be required to obtain satisfactory rock for use in rock slope protection. It is expected that the excavated rock will increase in volume by a factor of 1.3 over in situ volume but losses incurred during blasting, handling and processing, will reduce the quantity of available rock so that for in place volume on the embankment a balance factor of .8 of the in situ volume is considered reasonable for quantity estimates. A very large volume of shale will be available from required rock excavations so it is planned to incorporate unprocessed excesses in a rolled, rockfill section in the cofferdam or internally in the dam embankment.

Because of the tendency of the shale to break down during freezing and thawing, it will be necessary to use a more durable type of rock where the slope protection will be exposed to fluctuating water levels and atmospheric conditions. Granitic rocks, mainly granodiorite, suitable for this purpose are available in the vicinity of Deboullie Mountain located approximately 12 miles southeast of the Dickey site as shown on Plate No. 5. The granodiorite is massive, hard, durable and generally uniform in texture, color and composition. Access to the Deboullie area is possible for most of the distance on existing poor logging roads but extension by several miles of new road will be required. Total haul distance from the Deboullie area to Dickey is about 18 miles.

f. Concrete Aggregates. All the natural deposits of sand and gravel in the region contain a high proportion of flat, elongate and friable shale fragments derived from the local bedrock. Because of the slaty character of the shale, both the bedrock and the natural sand and gravel deposits are not considered suitable for use as aggregates in concrete.

At Deboullie Mountain, as previously discussed in conjunction with producing high quality rock slope protection, rock for production of suitable fine and coarse aggregates could be obtained by quarrying. In view of the large volume of concrete required, amounting to approximately 500,000 cubic yards, and the long haul distance from the Deboullie area, consideration will be given to the feasibility of also obtaining fine aggregates from the nearby sand and gravel deposits in the vicinity of the damsite. As a subsidiary operation to processing for selected gravels or by selective excavations, it may be possible, by adequate processing, to eliminate or reduce to tolerable limits the percentage of shale fragments in the natural materials to produce an acceptable fine aggregate.

CHAPTER III

TIDAL POWER PROJECT

DEPARTMENT OF THE INTERIOR PLAN

3-01 GENERAL DESCRIPTION

The basic plan envisioned by the Department of the Interior proposes Passamaquoddy developed as a peaking powerplant supplying a substantial portion of the peaking power requirements of an extensive marketing area embracing the New England States and New Brunswick. The plan utilizes the basic two pool concept developed in the I.J.C.'s report with the significant modification that inclined shaft turbines would be used in the powerplant in lieu of conventional vertical shaft turbine-generator units, and that the installed capacity would be one million kilowatts instead of 300,000 kilowatts.

The components of the I.J.C.'s plan, except the powerhouse, are incorporated into the Department of the Interior's plan without change. The unchanged features include tidal dams, the navigation locks and all filling and emptying gates.

POWERHOUSES

3-02 LAYOUT

The adopted plan proposes the construction of two identical 50-unit powerhouses, one at Carryingplace Cove and the second at Bar Harbor, as shown on Plate No. 1. Powerhouse No. 1 would be located on Mathews Island, as in the I.J.C.'s plan, with the headrace excavated across a narrow isthmus of Moose Island between Kendall Head and Redoubt Hill. A closure dam would connect the northwest end of the powerhouse to Moose Island. Powerhouse No. 2 would be located on the western peninsula of Moose Island near Bar Harbor with the headrace excavated across the causeway for Route 190 between Carlow and Moose Islands. A closure dam would connect the west end of the powerhouse to the mainland.

For economic studies cost estimates were required for installations of 30, 50, 70 and 100 power units. The 30-unit powerplant would be located at the same site as Powerhouse No. 1. Headrace and tailrace would be narrower to correspond to the smaller powerhouse. The 50 units would be installed in Powerhouse No. 1. The 70 units would include an additional 20-unit powerhouse at the location of Powerhouse No. 2 with appropriate headrace and tailrace. The 100 units would be contained in the two powerhouses as already described.

The switchyard would be built on an artificial fill near the northwest end of Powerhouse No. 1 as shown on Plate No. 1 where it would serve both powerhouses.

The powerhouses developed would be identical, and further description of one powerhouse will apply to both. The powerhouse would have 50 main unit bays, each 62 feet wide; two 83-foot assembly bays, one at each end; and four 55-foot service bays, located between groups of 10 units. The total length of the powerhouse would be 3,486 feet. Plate No. 2 shows the general plan of the powerhouse.

The powerhouse would be a reinforced concrete structure. The intake side of the structure housing the turbines is planned as a semi-outdoor type of structure with the deck at elevation 20.0 feet above mean sea level. Access roads and railroad would meet the powerhouse at deck level. Most of the mechanical and electrical equipment would be housed inside the powerhouse. Two outdoor-type 85-ton gantry cranes would travel on the concrete deck to unload, install, and service the 50 turbines, and operate the intake gates. Large openings in the deck, each covered with a removable hatch cover, would provide access to the turbines. The portion of the powerhouse over the draft tubes, containing the speed increasers and generators, would be of the indoor type. It would have reinforced concrete walls and a flat roof on steel trusses. Two 100-ton bridge cranes, travelling the full length of the powerhouse, would install and service the 50 speed increasers and generators. Five step-up transformers would be spaced along the deck at 10-unit intervals between the gantry crane tracks and the powerhouse roof. Two 20-ton gantry cranes would travel the deck over the draft tube openings and operate the draft tube gates.

3-03 TURBINES AND GENERATORS

Plate No. 2 shows the equipment setting and water passages which are in accordance with a manufacturer's submitted proposal and considered reasonable. The main unit includes a turbine, speed increaser, and generator all on an inclined axis.

The slightly-inclined propeller-type turbine would have adjustable blades, adjustable wicket gates, and fixed stay vanes. Wicket gates are required to prevent leakage. Turbine would have a full-gate rating of 14,000 horsepower at a 13.2-foot head and 45 revolutions per minute. A governor and operating mechanism are included with the turbine.

The speed increaser with a 10-to-1 ratio, would increase the shaft speed from 45 to 450 revolutions per minute, permitting the use of a smaller diameter, more efficient, and less costly generator and results in a better design.

The generator would be rated at 11,100 kv.-a. 0.90 power factor, 3 phase, 60 cycle, 13,800 volts, 450 r.p.m., complete with exciter. The generator and direct connected exciter would be complete with bearing relays, thermometers, water flow indicators, generator field shunt, space heaters, current transformers, etc. Included are also air to water heat exchangers, a carbon dioxide fire protection system, and thrust bearing to absorb the generator thrust due to inclination of the shaft.

3-04 MAIN UNIT BAY

The inclined axis turbine, with centerline at elevation -20.0, is set at a slight angle to the horizontal so as to permit the locating of the generator and speed increaser in the dry. Preliminary structural analysis indicated a thickness requirement of 6 feet for the end piers and 5 feet for the center pier. This requirement plus the water passage exit width of 45 feet established the width of the main unit bays at 62 feet. The generator floor is established at elevation -4.0 and as such provides four feet of concrete, minimum, over the draft tube. The floor level over the turbines was established at elevation +3.0 and provides mass concrete around the turbine for the inertia block.

The powerhouse deck was established at elevation 20.0 which provides 6.5 feet of freeboard above the upper pool maximum elevation of 13.5, and which also provides a working headroom of 14 feet in the mechanical and electrical equipment galleries. The walls for the generator room would extend the entire length of the powerhouse, and support the bridge cranes. The walls for the turbine area would extend the entire length of the powerhouse, and support the deck slab and gantry cranes.

The indoor type structure over the generator has the advantage that it would provide suitable electrical clearances for the high voltage equipment and transmission line take-off structures. The indoor type structure also offers the advantage of a dry inside area for the construction, operation and maintenance of the major electrical equipment. The powerhouse roof would consist of multiple ply roofing laid over "Q" decking supported by a steel truss framework.

3-05 ASSEMBLY BAYS

The 83-foot assembly bay provided at each end of the powerhouse would have two floor levels, elevation -4.0 and +20.0 as shown on Plate No. 3. The lower level would provide two assembly areas. One area, for the erection of turbines and transformers, would be serviced by one 85-ton gantry crane operating through metal-covered hatches in the deck. The other assembly area, for the erection of speed increasers and generators, would be serviced by one 100-ton bridge crane. A transfer car operating on transverse rails would be used for moving equipment between the two erection areas. The assembly bays would provide space for oil storage and purification, maintenance shop, washroom, and first aid and storage area. An office building, 24 feet by 83 feet, would be located on the elevation 20.0 floor as shown on Plate No. 3. The building at the southeast end would be used for offices for project administrative personnel and facilities for visitors. The building at the northwest end would be used for additional office space and for the powerplant supervisory control room.

3-06 SERVICE BAYS

A 55-foot service bay would be provided between each group of ten units as shown on Plates No. 2 and No. 3. These four areas, at elevation -4.0 would provide space for station service auxiliary equipment and space for repair of main unit equipment. These repair areas would be used during construction as additional assembly areas for erection of turbines, generators and speed increasers. The central portion of the area would be used for station service air-compressor rooms. The powerhouse drainage and unwatering sumps and pumps would be located in the downstream area of these service bays.

3-07 GENERAL ARRANGEMENT

The general arrangement of the powerhouse equipment is shown on Plate No. 3. The mechanical and electrical systems would be arranged in 5 groups of ten units each. A group control center would be located on the generator floor at the mid-point of each group. This control center would provide all necessary features for the remote control and operation of each of the ten units in the group. The generator and station service switchgear for each group of ten units would be located in the electrical equipment gallery, elevation 3.0, at the mid-point of the group. The main power transformer for a group would be located on the main deck, elevation 20.0 directly above the generator switchgear. The mechanical equipment gallery would be used for locating the governors, heat exchangers, piping systems and other mechanical equipment. A transverse utility gallery would be provided between each unit for the routing of mechanical piping and electrical circuits from the generator room to the mechanical and electrical equipment galleries. The powerhouse roof area would be used for location of high voltage equipment and take-off structures for aerial lines to the switchyard.

3-08 GATES, TRASHRACKS AND STOPLOGS

Five sets of intake gates would be provided for the 50 units. This would permit the simultaneous unwatering of three units while leaving two reserve sets for emergencies. Each set would consist of one wheeled and one slide gate. The gates approximately 34 feet 6 inches high by 16 feet 6 inches wide would each be constructed in two sections. The gates would be handled by the 85-ton powerhouse gantry crane and when not in use would be stored in the gate slots and supported by latches. The gates would be designed for emergency closure under full flow conditions with wide open wicket gates. Under these conditions, the slide gate would first be placed in one passage, then the wheeled gate would be placed in the remaining passage. Under these conditions the gates would close under their own weight.

Similarly five sets of draft tube gates would be provided for the 50 units to permit the simultaneous unwatering of three units, leaving two reserve sets. This quantity would be adequate to meet the requirement of project maintenance for a 50-unit plant. Each gate, approximately 53 feet 6 inches high by 22 feet 6 inches wide, would be constructed in six sections. The gate sections would be handled by the draft tube 20-ton gantry crane and when not in use would be stored in the gate slots and supported by latches. Because these gates would always be placed under a balanced head condition, all would be slide gates.

One set of trashracks would be provided for each of the 50 units plus one spare set for use in maintenance work. The trashracks would be placed in structural steel guides fastened to the upstream pier noses of the intake and would be handled by a 10-ton auxiliary jib hoist located on the 85-ton powerhouse gantry crane. This hoist would be equipped with a grab hook for use in removal of trash gathered in front of the trashracks.

One set of intake stoplogs would be provided for the fifty units and would be used for closure under a balanced head condition of any one of the intake passageways. This would permit maintenance of the intake gate slots. The stoplogs would be designed to operate in the trashrack guide slots and would be of such dimension and weight as to permit their handling by the 10-ton jib hoist on the 85-ton powerhouse gantry crane.

3-09 CRANES

Two 85-ton gantry cranes with a 52-foot span would be provided for the 50 units and would operate along the entire length of the powerhouse including the unloading areas at each end. The principal function of the cranes would be to handle the turbines and intake gates during construction and maintenance of the powerplant. The cranes would also be used to untank transformers, to unload railroad cars, and to handle trashracks and intake stoplogs. Each crane would have large rolling doors to permit complete enclosure of the area under the crane for use when servicing the turbines during inclement weather. A 115 k.w. diesel-generator set would be installed in each crane to provide power for hoisting and propulsion.

Two 100-ton bridge cranes, having a 70-foot span, would be provided in the generator room and would operate along the entire length of the powerhouse including the assembly and service bays. The cranes would handle the generators, speed increasers, turbine shafts and miscellaneous equipment during the construction and maintenance of the powerplant. They would take their power from a trolley bus located on the downstream side of the powerhouse.

There would also be two 20-ton draft tube gantry cranes to handle the draft tube gates for the 50 units. Each would be powered by a 115 k.w. diesel-generator set mounted on the crane.

3-10 POWERHOUSE CONTROL AND OPERATION

When required for load the powerplant would be operated to generate maximum power during short periods of time and would be under automatic control. The sequence of stopping and starting units could be preprogrammed by electronic computer from tide cycle predictions and recorded on punched cards or tapes for use by the automatic controller. The main supervisory control board would be equipped with a 50-unit status board permitting the withholding of selected units from automatic control if required.

A central supervisory board would be located in the west assembly bay of the plant and would provide equipment for automatic or manual control of all 50 units. Controls would also permit remote manual operation of switchyard breakers and disconnects. A unit-group control center would be located adjacent to each of the five groups of ten generators. From this center, an operator could control all operations for starting, loading and stopping the generators in his group.

3-11 AUXILIARY ELECTRICAL AND MECHANICAL SYSTEMS

All auxiliary electrical and mechanical systems for the tidal powerhouse described in the I.J.C. report of April 1961 were studied and estimated in detail. The systems for the present powerhouses are similar, and further detailed study is not warranted, since the over-all estimates are quite accurately made by adjusting the previous estimate.

3-12 MAIN POWER TRANSFORMERS

At each powerhouse the generators would be combined in five groups of ten each with a step-up transformer for each group. The transformers would all be 3-phase, forced oil-air type, delta-wye, rated at 111,100 kv.-a. with BIL characteristics as described in the I.J.C. report. At each powerhouse four transformers would have a high-voltage rating of 345 kv. and the fifth a rating of 230 kv.

3-13 STATION SERVICE

Station service electrical system for service areas would be taken from each of the five groups of generators by means of a 13.8-kv. feeder cable, when the powerhouse is in operation. The service for the aerial lines feeding the navigation locks and the tide gates, which form a part of the tidal power project, would be fed from a 13.8-kv. generator bus.

Inasmuch as the tidal powerplants will not operate continuosly, it will be necessary to use power from the interconnected system for station service and auxiliary power when the tidal plants are not operating. The station service in each group of ten units would be served by a 1,000-kv.-a., 3-phase, 13,200 - 480 volt transformer. Each transformer would be connected to a group bus which would furnish the auxiliary power to the ten units connected to the bus. Each transformer would be capable of carrying the load of its group as well as that of an adjacent group.

3-14 SWITCHYARD

The transmission lines in their entirety are included in the Department of the Interior report. Switchyard estimates were provided by the Bureau of Reclamation of the Department of the Interior and are included in the cost summaries of this report. The cost of main transformers is included with the powerhouse estimate, and the switchyard estimate, which had included it, is reduced by like amount in this report.

3-15 CORROSION CONTROL

All metal in the water passageways, including the runner hub and turbine shaft, will have a minimum 1/8" stainless-steel type 316 cladding, welded overlay or sleeves. It is noted that the International Passamaquoddy Engineering Board report of October 1959 contemplated that the turbine runner and certain other turbine parts would be fabricated of type 316 stainless steel.

All estimates are based on the corrosion prevention coatings and cathodic protection systems recommended in the I.J.C. report.

3-16 FISHWAYS

At the request of the International Passmaquoddy Fisheries Board, fishways for anadromous fish were planned in the I.J.C. report at the tidal powerhouse and emptying gates. In accordance with this request similar fishways have been provided at each end of Powerhouse No. 1 and No. 2 with a collection gallery along the downstream side of each powerhouse. The fishway at the emptying gates at Pope Islet would be the same as shown in the I.J.C. report.

HEADRACE AND TAILRACE

3-17 DESIGN

The headrace channels were designed to minimize hydraulic losses without requiring excessive excavation. The bottom of the channel for Powerhouse No. 1 varies from elevation -44 at the entrance, to elevation -50 at the narrowest part of the channel and to elevation -40.7 at the powerhouse. The bottom of the headrace channel for Powerhouse No. 2 is level at elevation -40.7.

The bottoms of the tailrace channels for both powerhouses vary from elevation -67 at the powerhouse to about elevation -35 in Cobscook Bay.

Average velocities in the headrace channels would be about 3.5 feet per second and in the tailrace channels about 3 feet per second.

3-18 EXCAVATION

The part of the excavation of the channels above high tide would be used for cofferdams. Cofferdams would be constructed, the work areas in the channels unwatered, and the work continued in the dry. It is planned to use the material excavated from the channels for Powerhouse No. 1 in the permanent features of the project. Since construction of Powerhouse No. 2 will be scheduled in the last phase of development, only a small portion of the material excavated from the channels could be used; the remainder would be wasted.

3-19 COFFERDAMS

In estimating the cost of cofferdams the same design is used as in the I.J.C. report. The quantities of materials vary with the number of units, 30, 50, 70, or 100, to be installed. Sources of materials for cofferdams also vary, being dependent upon what materials would be available in the early stages of construction. The length of cofferdams at Powerhouse No. 2 exceed those of Powerhouse No. 1 because of greater distances between suitable abutments.

MISCELLANEOUS ITEMS

3-20 SERVICE FACILITIES

The service facilities consist of maintenance shops, warehouse, utilities, land plant, floating plant, housing facilities, parking areas, service and access roads, and an access railroad spur to each powerhouse. The warehouse and storage area would be at Carryingplace Cove as in the I.J.C. report.

3-21 RELOCATIONS

All public and private facilities interrupted by the proposed construction would be relocated to give the same service as before the project was started. The costs of the work necessary to make the owners whole would be included as project costs in accordance with established procedures. These costs for Powerhouse No. 1 are increased from the I.J.C. report for the extension to a wider headrace. The same bridge is used as the one in the I.J.C. report for carrying the following facilities across the channel into Eastport; - State Highway Route 190; a single track branch line of the Maine Central Railroad; the water supply line to the City of Eastport; two power circuits of the Bangor Hydroelectric Company; one cable and 22 wires of the New England Telephone and Telegraph Company; and Western Union communication wires.

The wider headrace for the waterway to Powerhouse No. 1 requires removal of the sides of Kendall Head on the westerly side and Redoubt Hill on the eastern side. This would cut off the roads leading to the houses on the top of the two hills. Relocation of the access and utilities to both areas is included in the plans and cost estimates.

The same highway, railroad, and utilities would require relocation across the headrace of Powerhouse No. 2 by means of a bridge similar to that across the headrace of Powerhouse No. 1. The crossing of the water pipeline to Eastport is at Bar Harbor and along the line of the powerhouse. Since the relocation would not be completed before the construction for Powerhouse No. 2 is started, a temporary waterline would be required prior to construction of the permanent replacement.

3-22 LANDS AND DAMAGES

The real estate costs have been prepared by an appraiser familiar with the area and are additive to the real estate costs included in the I.J.C. report. The additional cost of widening the taking line for the wider approach channel to Powerhouse No. 1 is added.

The western peninsula of Moose Island would be acquired for Powerhouse No. 2, with a construction area on the southeastern end and another at the northwestern end. A strip along the southeast line of the approach channel will be acquired, also areas for the abutments and approaches to the proposed replacement bridge. All of Carlow Island would be included in the taking; any remainder after the bridge construction would be developed for the use of visitors as described in Chapter VI. All lands and damages in Canada remain the same as in the I.J.C. report. Damages to waterfront property, caused by the tidal regime for the high and low pools, would appear to be unchanged from those developed in the I.J.C. report.

3-23 OPERATION AND MAINTENANCE

The operating and maintenance staff of a hydroelectric power installation is a large part of the annual costs. The estimate of operation and maintenance annual cost for the increments of size of the tidal powerhouses now under study is developed from the I.J.C. report. The staff for locks, dams and emptying and filling gates would be the same, with a cost increase in accordance with present wage rates. The staff for the varying sizes of powerhouse would increase with the number of units, as would the amount estimated for annual supplies. The staff would include a small executive section, an engineering section, an operating section to provide necessary around the clock service, and a maintenance section on an 8-hour day basis plus emergency service.

SUBJECTS FOR FUTURE STUDY

3-24 PUMP-TURBINE UNITS

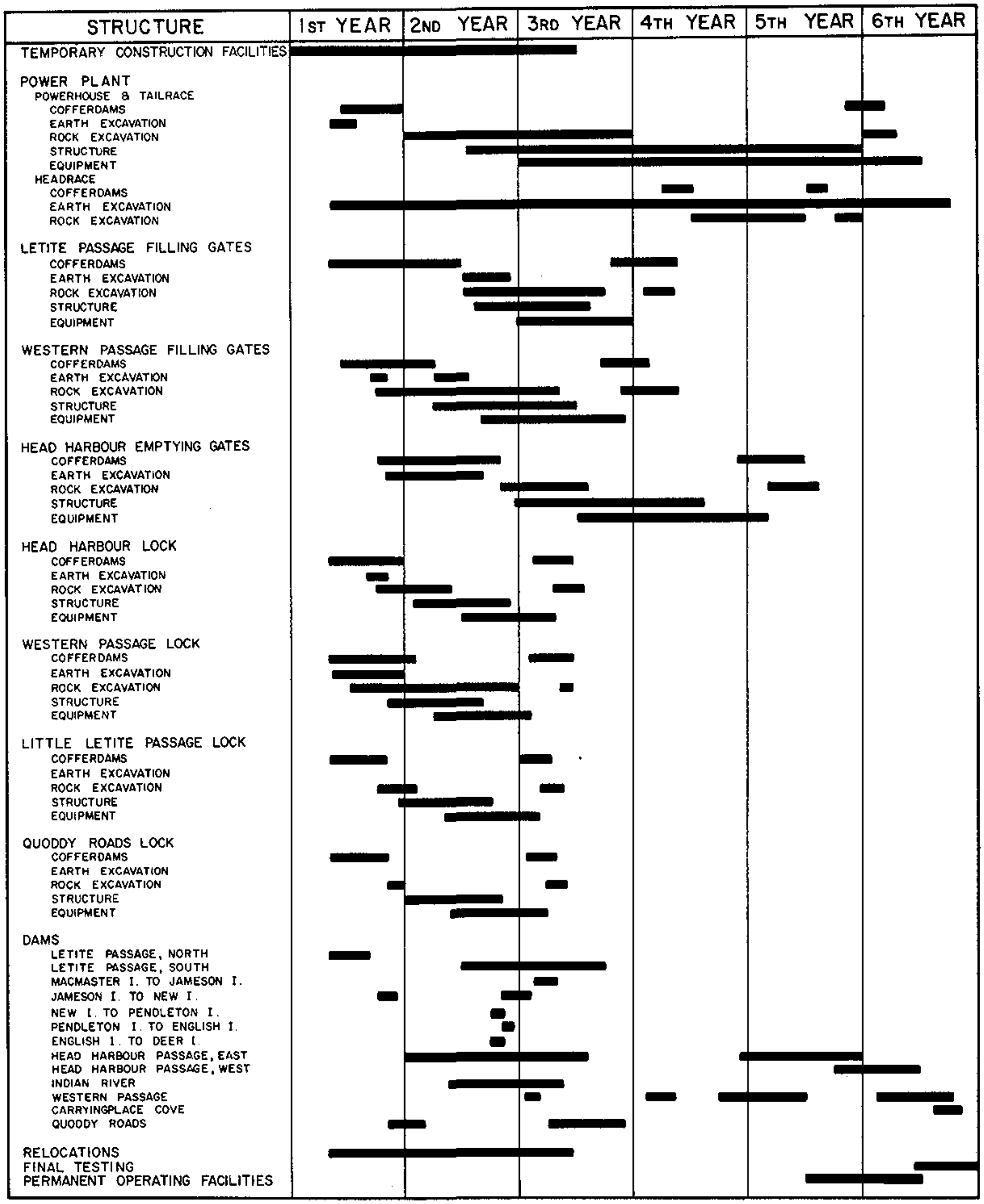
In searching for ways and means to improve the economics of the tidal power project, various ideas have been conceived. One of these, which is worthy of further study, is that of using pump-turbines to increase the peak power generation during periods of neap tides. Using off-peak power, available from 10 p.m. to 6 a.m., the reversible units would pump water from the low pool to the high pool.

Then, during the daily period of peak demand, these same units would generate power as the water in the high pool would flow back through them into the low pool. By this means, the firm generating capability of Passamaquoddy could be realized, as the additional water and head could be used to extend the period of on-load operation, thus offering more flexibility in fitting tidal power to the load.

3-25 DAMS, COFFERDAMS, AND GATES

There are several features where study during the design phase of the project might result in a reduction of cost. The tidal dams and cofferdams present many problems of design and construction. General and detailed hydraulic model studies and extensive deep water drilling would appear warranted. Further investigation may show that prefabrication of filling and emptying gates with a floated-in construction method would provide a saving.

CONSTRUCTION SCHEDULE



TIDAL POWER DEVELOPMENT

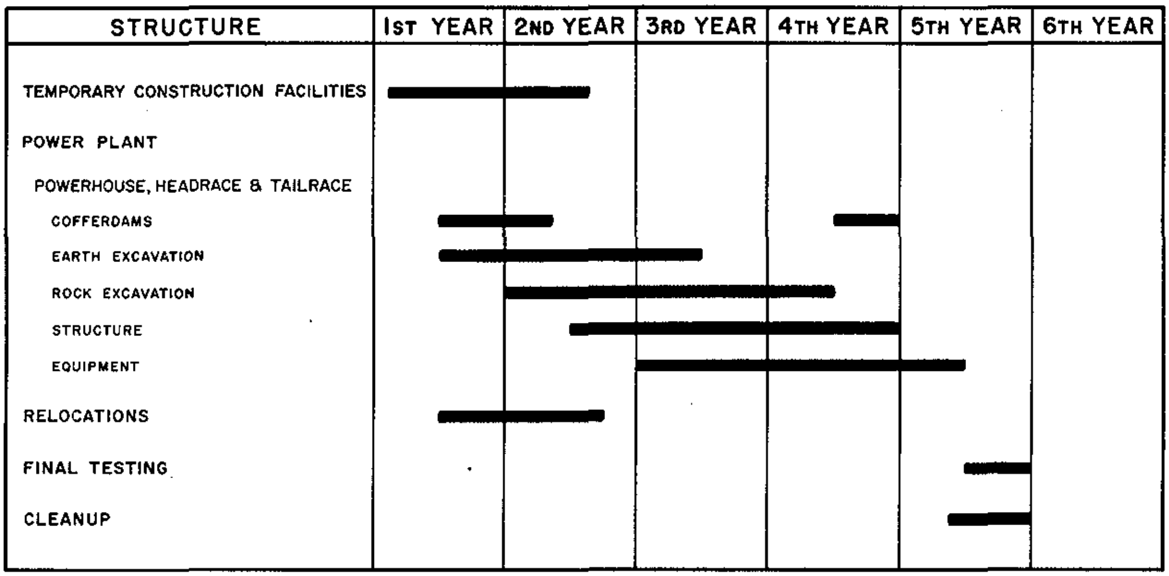
CONSTRUCTION SCHEDULE

POWERHOUSE NO. I - 50 UNITS

MARCH 1964 TG7-371

SCHEDULE I

CONSTRUCTION SCHEDULE



TIDAL POWER DEVELOPMENT

CONSTRUCTION SCHEDULE

POWERHOUSE NO. 2 - 50 UNITS

MARCH 1964 TG7-372

SCHEDULE 2

CHAPTER IV

DICKEY PROJECT, SAINT JOHN RIVER

4-01 GENERAL PLAN

The site selected for the river hydroelectric project is on the main river immediately above the confluence with the Allagash River as shown on Plate No. 5. The geologic features of the site have been described in a previous chapter. The general plan of the development is shown on Plate No. 6. The main dam across the river and the dikes across the adjoining saddles would be of the earthfill type. All structural features would be located on the right bank and in general founded on rock: the low level outlet tunnels, which would be used for diversion during construction; the powerhouse with tailrace discharging into the Saint John River; and the spillway which would discharge at infrequent times through a stilling basin into the Allagash River. The maximum and minimum reservoir elevations would be 910 and 870 feet above mean sea level, thus providing a 40-foot drawdown.

4-02 HYDROLOGY

The drainage area above the Dickey site is 2,725 square miles. Area and capacity curves for the Dickey site, shown on Plate No. 10, were developed from the latest available U. S. Geological Survey quadrangle sheets, scale 1:62,500. At maximum elevation of 910 feet, the reservoir area would be 88,600 acres and its capacity 8,080,000 acre feet. At drawdown level of 870 the reservoir area would be 58,500 acres and its capacity 5,180,000 acre feet.

Tailwater rating curves were developed for the spillway and the powerhouse. Since the stilling basin at the end of the spillway chute would discharge into the Allagash River just above the cutoff, its tailwater would be controlled by the new channel. The estimated rating curve is shown on Plate No. 10. The rating curve at the powerhouse shows that tailwater levels there would be controlled by the Lincoln School dam. The static maximum, minimum and average tailwater elevations would be 605, 597, and 601, respectively.

Streamflow at the Dickey site was assumed to be the same as at the Dickey gaging station two miles upstream. Records at the gage indicate the following:

Drainage area, sq. mi.	2,700 (approx.)
Period of record	Oct. 1946 - Sept. 1962
Average discharge, c.f.s.	4,600
Minimum Discharge, c.f.s.	129
Date	17 Sept. 1948
Maximum discharge, c.f.s.	71,700
Date	15 May 1961

Two important hydrologic events have occurred since the I.J.C. study: the most critical three-year drouth, 1955-58; and the greatest flood, May 1961. These events are taken into consideration in the present study.

The streamflow follows a normal annual pattern. Melting snow produces high rates of runoff in April and May after which the flow diminishes gradually and then remains quite uniform until the following spring, except for occasional rises due to rainfall. Then the cycle repeats. The following tabulation of mean monthly discharge illustrates this cycle:

Month	Mean Discharge, c.f.s.
April	12,460
May	16,300
June	5,290
July	3,040
August	2,360
September	2,150
October	3,350
November	4,340
December	2,450
January	1,210
February	740
March	1,330

In order to determine the regulated flow available at the Dickey site storage-draft curves were developed for periods of deficient streamflow, using records of flow at the Dickey gaging station. The critical periods were found to be 1947 to 1948 and 1955 to 1958. The following tabulation gives the storage and regulated flow for various values of drawdown:

Maximum Drawdown (feet)	Active Storage (acre-feet)	Regulated Flow (c.f.s.)
10	845,000	2,520
20	1,600,000	3,560
30	2,300,000	4,100
40	2,900,000	4,370

In computing the regulated flows, an allowance of 50 c.f.s. was made for losses by evaporation and leakage. For the selected maximum drawdown of 40 feet, the active storage would be 2.90 million acre-feet, and the regulated flow 4,370 c.f.s.

An analysis was made of the time required to fill the Dickey reservoir. With the intakes built as shown on Plate No. 7, the reservoir would have to be filled to elevation 870 before power generation could begin. This would require the accumulation of 5,180,000 acre-feet of water. In filling the reservoir consideration would need to be given to the water requirements of downstream plants, of which Beechwood, with 102,000 kilowatts installed, requires the most water. Assuming that Beechwood operates at 60 percent load factor and an average net head of 58 feet, its average water requirement is 14,600 c.f.s. It was assumed that the flow at Beechwood could be reduced to this average, 14,600 c.f.s., as a minimum, by storing water at Dickey except that a minimum discharge of 500 c.f.s. would be released at all times to maintain a reasonable low water riverflow immediately below the dam. It is also assumed that water in storage would not be drawn on during the filling period to make up any deficiency should natural flow at Beechwood fall below the 14,600 c.f.s. level. Under average flow conditions, filling of the reservoir would begin in April and be completed in about 2 years.

4-03 RESERVOIR

The extent of the proposed Dickey Reservoir at full pool elevation 910 is shown on Plate No. 5. It would extend about 47 miles up the Saint John River and cover an area of 88,600 acres. A more detailed description will be given later under the subject of "Lands and Damages," in Paragraph 4-09. The reservoir would be contained by the main dam and saddle dikes at five scattered locations, required to prevent flow into adjacent watersheds.

4-04 EMBANKMENT AND SADDLE DIKES

The top of the main embankment was set at elevation 925 to provide 15 feet of freeboard over the maximum normal operating pool. A 60-mile-per-hour wind (velocity over water) acting on the effective fetch of 3.14 miles from the northwest, would generate 4.6-foot waves. These waves would run up 3.8 feet on the 1-on-3, riprapped slope. In addition, there would be a set-up of 0.7 foot, on an effective reservoir length of 23 miles. The sum of set-up plus wave run-up would be 4.5 feet, leaving a freeboard of 10.5 feet. The freeboard provided above maximum spillway surcharge of 8.6 feet, an extremely rare condition, is 6.4 feet without wind and wave action.

Typical cross sections of the main embankment across the river and the secondary dam on the right bank are shown on Plate No. 7.

Transition zones between different materials, details of surface protection and control of seepage follow conventional practice.

The upstream face of the embankment would have 4 feet of rock slope protection placed on a 2-foot layer of gravel bedding. Above elevation 860, where the pool is subject to fluctuation, the rock for slope protection would be selected. The downstream slopes would be faced by 3 feet of processed gravel above elevation 610, below elevation 610, the downstream toe would be protected by 4 feet of "select" rock on a 2-foot gravel bedding.

To prevent overflow into the Saint Francis River basin a dike would be required on Falls Brook, and another on Hafey Brook. Dikes would also be required on Campbell Brook, Blue Brook and Cunliffe Brook to prevent overflow into the Allagash River basin. All dikes would be earthfill type, constructed of materials found within three or four miles of the respective sites. The locations of the dikes are shown on Plate No. 5.

4-05 LOW LEVEL OUTLETS AND RIVER DIVERSION

Two 24-foot tunnels driven through the right abutment would be used during construction to pass riverflows after the spring freshet recedes. A study shows that the 10-year construction-season flood passing through the tunnels would raise the level in the reservoir to elevation 627.2. A closure section across the river would have to be raised above this elevation as rapidly as possible after the spring breakup. The following spring flood could be passed through the tunnels and over a saddle at elevation 662.5 to the right of the powerhouse location. With a gap of about 1,000 feet in the embankment across the saddle the maximum spring flood would raise the level in the reservoir to elevation 672.6. With the flow confined to the two 24-foot tunnels the maximum flood of record would raise the reservoir to elevation 699. The section of the dam closing the 1,000-foot gap would be raised to above this elevation during the construction season.

The two 24-foot tunnels described in the previous paragraph would also be used for releases during reservoir filling. Two 90-inch fixed-cone dispersion valves would be installed in each tunnel to control the discharge. The valves and their vertical-lift emergency gates would be located in a shaft immediately upstream from the centerline of the dam as shown on Plate No. 7.

4-06 SPILLWAY

The spillway design flood for the Dickey site was developed in the same way as the spillway design flood for the Big Rapids site. (See report of the International Passamaquoddy Engineering Board; Appendix 12, Auxiliary River Hydro Developments; par. 12-08 f, p 12-27). The maximum possible rainfall over the Dickey drainage area is very nearly the same as for the Rankin Rapids drainage area. Figure 5, Plate 12-6, same reference, shows the component hydrographs of the Rankin Rapids spillway design flood. The two component hydrographs representing flow from the drainage area of Saint John River were added together. Then the ordinates were adjusted to the drainage area above the Dickey site, and base flow was added. This gave the natural hydrograph at the damsite. The hydrograph of inflow to a full reservoir would have a higher and earlier peak because of loss of valley storage and shorter travel time. Accordingly, the peak of the hydrograph was increased by 35,000 c.f.s. and the hydrograph was reshaped, retaining the same runoff volume, to obtain the inflow hydrograph, shown on Plate No. 10.

An ungated overflow spillway rather than a gated control structure was chosen for the Dickey development to provide better flood control. In addition, an ungated structure would not require a power supply or operating personnel.

A relationship was developed between maximum surcharge and length of spillway crest by trial routings of the spillway design flood through the Dickey reservoir. On the basis of this relationship, a crest length of 500 feet was selected. After the shape of the spillway crest and the spillway rating curve was determined, the spillway design flood was again routed through the spillway to check the design. It was assumed that all other outlets would be closed. The routing was started with the reservoir 0.75 foot above spillway crest, corresponding to a spillway discharge equal to the base flow. The maximum surcharge was 8.6 feet, and the maximum discharge was 50,000 cubic feet per second, which were satisfactory.

Since the control structure would be subject to ice thrust, the upstream face of the control weir would have a slope of 1 on 1. The crest would be shaped to conform to the lower nappe of a freely-falling sheet of water. A design head of 7.0 feet was used. Heads in excess of the design head would produce pressures somewhat less than atmospheric on the crest of the weir.

The crest structure would discharge into a rock chute which would gradually converge from a width of 500 feet, spillway crest length, to a width of 250 feet in about 1,500 feet. The upstream 800 feet of the chute would have a slope of 0.2 percent, then 700 feet at a slope of 13.8 percent, then 1,650 feet at a slope of 11.8 percent into a stilling basin with floor at elevation 590. The chute would be unpaved where it is in sound rock and the lower 1,600 feet and stilling basin would be paved with concrete and have concrete side walls.

A standard hydraulic jump stilling basin would be provided at the downstream end of the chute, as shown on Plate Nos. 6 and 7 to give necessary control of the high flow velocities which would occur in the chute. The horizontal apron at the basin would be at elevation 590, sufficiently below river tailwater elevation to assure the formation of a hydraulic jump at all levels of tailwater. Concrete walls of the stilling basin would rise 50 feet above the floor to provide ample freeboard above spillway design flood tail-water and to serve as abutments for the highway bridge.

The channel of the Allagash River would be improved from the stilling basin to its mouth, a distance of about 8,700 feet. The bottom width would be 400 feet, and the side slopes 1 on 2. The bottom slope would be about one-foot per thousand feet.

4-07 INTAKE AND PENSTOCKS

The most economical arrangement of penstocks and intake structure was found to be with the intake through a high rock knob on the right bank. The invert of the 18-foot penstocks was set at elevation 835, an elevation determined by an economic relationship between width and depth of the approach channel referred to the drawdown level of 870. This elevation provides 17 feet of submergence over the top of the penstocks. The excavated channel from the reservoir to the intake structure would be ten feet lower in accordance with common practice.

The intake would be a concrete gravity structure with the top elevation the same as the dam crest, elevation 925. The service road across the dam would cross the top of the intake structure. Each intake would have a single water passage with an 18- x 30-foot trashrack and a 12.5- x 25-foot emergency vertical-lift headgate. The gates would be remotely controlled from the powerhouse. Stoplogs, placed in the trashrack slots, would be used when inspection or repair of the gate slots is necessary.

The penstocks from the intake to the powerhouse would be constructed of welded steel. The eight main unit penstocks would be

18 feet in diameter and the station service units would be supplied through a single 4-foot 3-inch penstock which would branch at the powerhouse to the two units. Maximum velocity in the main unit penstocks would be 23 feet per second. Plate thickness would be designed for maximum pressures accompanying emergency interruption of full turbine load with maximum pool head. The length of the penstocks was made as short as possible, 1,230 feet, to obviate the need for surge tanks and thus avoid the problems of icing that would occur with peaking operation of a hydroplant during the extremely cold winters at the Dickey site.

To prevent icing of the penstocks, they would be located in a cut and backfilled to a depth of three feet over the top. This would place the centerline well below the frostline with a depth of six feet.

4-08 POWERHOUSE

As stated earlier the powerhouse would have an ultimate capacity of 760 mw. with 8 - 95,000 kw. generators. The cost estimate includes the structure for the ultimate development in the initial 190 mw. installation. For the 380 mw., 475 mw. and the 760 mw. installations the costs for turbines, generators, penstocks and accessories are added. The powerhouse would be of the indoor concrete type with ultimate installation of 8 generating units driven by vertical-shaft, Francis-type, hydraulic turbines spaced 63 feet on centers. Each turbine would be connected by an 18-foot diameter steel penstock extending approximately 1,230 feet to the intake structure. The switchyard would be located downstream from the powerhouse on the right bank of the tailrace channel and connected by aerial lines to the power transformers on the draft tube deck of the powerhouse. Access would be by heavy duty road from the railhead at Saint Francis, Maine to the south end of the plant where the assembly, control, service, and office areas are located. The powerhouse layout is shown on Plate No. 8. The bridge crane would have a rated capacity of 375 tons.

The centerline of turbine distributors would be set at elevation 601.0. Each of the eight vertical, Francis-type, steel-spiral-case, hydraulic turbines would develop 130,000 h.p. at full gate, at the rated head of 275 feet and at 128.6 r.p.m. The governors would be equipped with means for adjusting the rate of gate movement to any value between 5 and 30 seconds for full gate opening or full gate closing stroke.

The generators, directly connected by vertical shafts to the turbines, would each be rated at 105,500 kva., 60° C temperature rise, class "B" insulation, 13.8 kv., 0.90 power factor, 3-phase, 60-cycle and with a direct-connected exciter. Reactances, WR^2, runaway speed, and thrust bearing loading would not exceed values available in standard design machines. Power for the station service system would be supplied by two station service generators driven by hydraulic turbines. The generators would be rated at 1,250 kva., 480 volts, 0.80 power factor, 3-phase, 60-cycle and with a speed of 720 r.p.m. Conventional fire protection, cooling, heating, and utility systems would be provided.

Four, 3-phase, 243,000 kva., 13.2-13.2-230 kv., three winding, delta-delta-star connected, type FOW transformers would be provided. Each transformer would be connected to two generators and sized for 115% of the rated generator output. The transformers would be located on the tailrace deck, and each transformer would be connected to the switchyard by an aerial line.

The switchyard would be a 230 kv. yard and would be remote-controlled from the powerhouse.

4-09 LANDS AND DAMAGES

The site of the Dickey dam and reservoir is located in Aroostook County, Maine, as shown on Plate No. 5. The damsite is about 13 miles above the town of Saint Francis, Maine, and just above the point where the Allagash River enters the Saint John River. The reservoir extends from the damsite 57 miles to the farthest point of flooding on the Saint John River. The backwater extends 25 miles up the Little Black River and 23 miles up the Shields Branch of the Big Black River. (The Shields Branch is called Riviere St. Roche in Canada.)

Land required for the project is approximately 110,000 acres which consists of water area of approximately 88,600 acres at maximum pool elevation 910, and 2,000 acres for work areas at the dam and saddle dikes with necessary access and adjacent borrow areas. The total area includes some islands that would be formed by the reservoir and a 300-foot buffer and access strip around the perimeter. A separate borrow area of 20 acres at Deboullie Mountain is included as a source for concrete aggregate and stone facing.

The reservoir would extend into the Province of Quebec, Canada at three places. On the Shields Branch (Riviere St. Roche) of the Big Black River about 1,200 acres in Canada would be flooded. This area is developed with farms, roads, and bridges. On two branches of the Little Black River about 2,400 acres of forest would be flooded. The costs of relocation of the public facilities in Canada are included in the relocation costs.

Most of the land required for the Dickey project is in large tracts of timber held mainly for pulpwood cutting. There are some abandoned farms reverting to woodland. There is a built-up area in the hamlet of Dickey about 1½ miles above the damsite. Highway No. 161 serves the community and terminates above the hamlet of Dickey. The population of the entire project area is estimated at 700. About 240 tracts of land would have to be acquired for the project.

An appraisal of the woodland required for the project was made by an appraiser familiar with timberlands in the region. All land was classified according to its highest and best use, and appraised on the basis of fair market value in January 1964. An allowance was made for the value of standing wood growth on all timberland, and also for severance. Severance costs provide an equal access in cases where present access would be flooded out. To avoid isolation of timberlands on the north side of the Saint John River, a ferry with landings on the north and south sides of the reservoir is included in the estimate. An access road leads from the ferry landing to connect with the road along the Allagash River and with Route 161 just below the damsite. Improvements on the land were estimated separately. They include dwellings, barns, lumber mills, churches, schools, etc. There are no known mineral rights.

Water rights include two breached dams on the Saint John River. International water rights on the Saint John River arise from the treaty of August 9, 1842, between the United States and Britain (the Webster-Ashburton treaty), which provides for common use of the waters of the Saint John River to promote commerce and transportation for the benefit of the United States and Canada. The only use made of the river in the sense of the treaty is the floating of logs and pulpwood to downstream points. The design of the dam provides for a logway to maintain this traffic. No fishways would be required since the upstream movement of anadromous fish is blocked downstream by natural obstacles.

4-10 ROAD NETS AND RELOCATIONS

Access roads and relocations necessary in connection with the construction of the Dickey project are shown on Plate No. 5. The Dickey site is reached from St. Francis by Route 161. The bridge over Allagash River would be reconstructed for heavy loads for project purposes. The road leading up the north side of the Allagash River will be relocated within the work area and carried across the stilling basin by a bridge, as shown on Plate No. 6.

Access to the sites of the Falls Brook and Hafey Brook dikes would be by means of a road across the Lincoln School dam and existing and relocated tote roads, as shown on Plate No. 5. Access to the site of the Campbell Brook dike would be by a new road connecting to the tote road along the north side of the Allagash River. This road would also serve the ferry landing and recreation area to be constructed on the south side of the reservoir. There are no known roads near the sites of the Blue Brook and Cunliffe Brook dikes. Access would be by haul roads which are a project cost. Access roads for woods operations are included as severance costs in lands and damages.

There is a power pole line of the Maine Public Service Company on Route 161, and a pole line of the Fort Kent Telephone Company which require removal within the Dickey project. There is a single-wire telephone line of the Maine Forest Service in the reservoir area. It is understood that future communications of this Service are to be handled by radio and no relocation would be necessary. There are about 250 graves in three cemeteries which will require relocation of an estimated cost of $50,000.

4-11 SERVICE FACILITIES

Since the Dickey project is about 180 air miles from the tidal project, it will be practically independent for operating services and most maintenance work. Therefore, the project would be provided with maintenance shops, vehicle servicing shops, warehousing, housing for key employees, land vehicles and equipment, and marine plant. The service facilities at the Dickey project would also serve the reregulating dam about 11 miles downstream at Lincoln School.

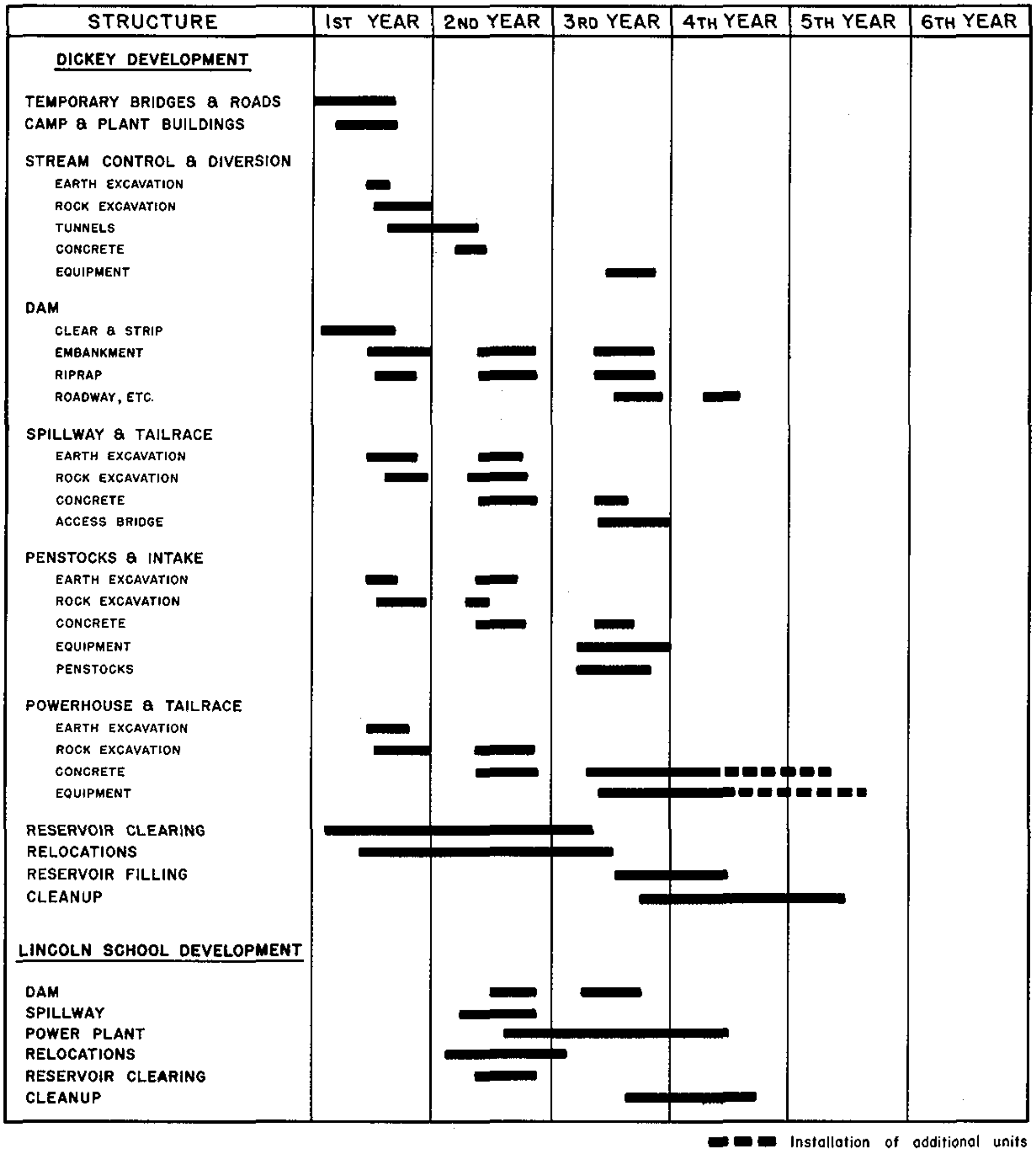
4-12 OPERATION AND MAINTENANCE

An operating and maintenance staff of approximately 45 would be required to operate the full development at Dickey; about two-thirds would be engaged on maintenance work. A high degree of automatic control and centralized operation is anticipated. The maintenance force would handle all preventive maintenance. The operation of the Lincoln School project would be controlled from the Dickey project. A common maintenance force would be used. The estimate for operation and maintenance is based on the study made in the I.J.C. report, adjusted to present conditions.

4-13 FUTURE CONSIDERATIONS

There are other possibilities for developing power on the Upper Saint John River which may be investigated for comparative purposes during the project design stage. One is a power reservoir at elevation 910 at Big Rapids, coupled with one at Lincoln School with maximum pool elevation 630. This combination was studied in the preparation of the I.J.C. report. Another would be a dam at Dickey with maximum pool elevation about 910, but with intake and powerhouse on the left bank of the Saint John River at Lincoln School. This scheme would require a high dam on Falls Brook about five miles downstream of the present dike, a two-mile tunnel through the mountain to the Lincoln School damsite and a slightly higher reregulating dam at Lincoln School. The high head powerplant at Lincoln School would discharge two turbines into the Saint John river for continuous power, and six turbines into the Lincoln School reservoir for peak demands. Flow from the Allagash and the discharge from the six high head turbines would be utilized by two turbines in the Lincoln School powerhouse.

CONSTRUCTION SCHEDULES



DICKEY & LINCOLN SCHOOL

CONSTRUCTION SCHEDULES

MARCH 1964

AG7-135

SCHEDULE 3

CHAPTER V

LINCOLN SCHOOL PROJECT, SAINT JOHN RIVER REREGULATION

5-01 FUNCTION OF LINCOLN SCHOOL

The average regulated flow from the Dickey powerplant would be 4,370 c.f.s. with a maximum discharge of about 48,000 c.f.s. In order that the Dickey discharge might be better controlled and utilized a reregulating reservoir would be desirable. An ideal site was found approximately 11 miles downstream on the Saint John River at Lincoln School. Here a dam will be constructed, including a powerhouse, that will impound the Dickey discharges and where the discharge will be regulated for more effective use by existing downstream hydroplants at Grand Falls and Beechwood, New Brunswick. Coincidentally it will have the capability of generating power. The general plan of the proposed dam is shown on Plate No. 9.

5-02 HYDROLOGY

The active storage capacity of 16,000 acre-feet at Lincoln School would be sufficient for reregulation of the discharges from Dickey on a monthly basis but not enough to regulate the flow from the uncontrolled drainage area. The controlled average outflow from Lincoln School would equal the regulated flow from Dickey plus the minimum flow, 200 c.f.s., from the uncontrolled drainage area of 1,361 square miles. The 2,900,000 acre-foot active storage, 40-foot maximum drawdown, at Dickey would permit a regulated average flow of 4,370 c.f.s. after deducting 50 c.f.s. for evaporation and leakage. Thus the regulated average flow from Lincoln School would be 4,570 c.f.s.

The tailwater rating curve for natural conditions at the Dickey site shows that the head loss between the two sites would be negligible, even when the Lincoln School pool is drawn down. The pool level at Lincoln School would vary from a maximum of 605 feet to a minimum of 597 feet above mean sea level. Area and capacity curves determined from U. S. Geological survey quadrangle maps, scale 1:62,500, are shown on Plate No. 10.

5-03 RESERVOIR

The Lincoln School reregulating reservoir would extend 11 miles upstream on the Saint John River to the Dickey Dam and up the Allagash River to the Dickey spillway discharge channel, as shown on Plates No. 5 and No. 6. It would have an area of 2,200 acres at full pool elevation of 605 feet above mean sea level.

5-04 EMBANKMENT

Because rock is deeply buried below the bed of the river, an earth dam is the most economical structure. The top of the embankment was set at elevation 620 to provide 15 feet of freeboard over the maximum normal operating pool level and spillway design flood pool level, which are at the same elevation. A 60-mile wind from the direction of maximum fetch (SW, 1½ miles) would result in 3.5 foot high waves which would ride up 5 feet on the upstream slope. There would remain 10 feet of freeboard above the level of wave action.

The design of the earth embankment is similar to that used by the I.J.C. for the Lincoln School project. Plate No. 9 shows a typical embankment section.

5-05 RIVER DIVERSION

It is assumed that construction of the Dickey Dam would be started in advance of the Lincoln School Dam so that the Dickey reservoir would be available to control floods from its drainage area. In this case, the flood discharge at the Lincoln School site during construction would be only the discharge from the uncontrolled drainage area. On the other hand, construction of Lincoln School Dam might be scheduled to start some time after two units have been installed in the Dickey powerhouse. In the latter case, the discharge from two units, 10,000 c.f.s., would be added to floods from the uncontrolled area. The record spring flood on the Allagash River is 28,800 c.f.s. from a drainage area of 1,260 square miles. On the basis of drainage area ratios, it is estimated that the maximum discharge from the total uncontrolled area of 1,361 square miles was 31,300 c.f.s. The total estimated discharge to be passed at the Lincoln School site would thus be 41,300 c.f.s.

It is planned that the river would be diverted initially over the partly completed powerhouse foundation and later over the spillway. The powerhouse, Plate No. 9, would be constructed in two stages, the first of which would consist of the intake up to its final elevation, and the powerhouse substructure to the bottom of the spiral case. Piers would be constructed above the draft tube outlet. Closure of the main embankment across the river channel would be initiated by a rockfill cofferdam upstream which would force the river flow through the partially completed powerhouse. The discharge capacity of the powerhouse would be 41,300 c.f.s. with the pool at elevation 562, which would pass the record spring flood from the uncontrolled area, 31,300 c.f.s. plus the discharge from the Dickey powerhouse, 10,000 c.f.s.

On completion of the main embankment and the spillway, the headgates and downstream bulkheads would be installed in the powerhouse area, the area pumped out, and the powerhouse construction resumed. After closure of the headgates, the pool would have to rise from about elevation 540 to elevation 580 (5 feet above spillway crest) before the river flow could be passed over the spillway in sufficient quantity for downstream requirements. Since only 13,000 acre-feet would be involved in this operation, it might be advantageous to draw on Dickey storage to raise the pool rapidly. If desired, some flow could be released through the intake gates during the filling operation.

In view of the foregoing, and the low head at the project, plus the fact that all releases for reregulation could be made through the spillway, no low-level outlets are planned.

5-06 SPILLWAY

The spillway would be designed to meet the following requirements:

a. It must pass river flows while construction of the powerhouse is being completed.

b. It must, together with the powerhouse, reregulate the discharge from the Dickey powerhouse, and pass flood flows in excess of the capacity of the Lincoln School powerhouse.

c. It must pass the spillway design flood.

The spillway design flood for the Lincoln School spillway was computed by adding the ordinates of four hydrographs shown on Plate No. 10 and described as follows:

a. Dickey Powerhouse Discharge. - The power output at Dickey required to supplement the Passamaquoddy output is shown on Figure 9 of the report of the Department of the Interior dated July 1963. The load pattern of the first Wednesday was followed, assuming a maximum load of 760,000 kilowatts from 5 to 6 P.M. The average discharge for each hour of the day was computed. For simplicity, it was assumed that this pattern of discharge would repeat daily during the spillway design flood.

b. Dickey Spillway Discharge. - The spillway design flood inflow was routed through Dickey reservoir, assuming powerhouse discharge as described above, to obtain the Dickey spillway discharge.

c. Upper Allagash. - The flow from the upper Allagash drainage area of 720 square miles, which is completely regulated by lakes, was assumed to be 6,000 c.f.s.

d. Lower Allagash Plus Local. - The hydrograph representing runoff from the lower part (540 sq. mi.) of the Allagash drainage area is shown on Plate 12-6, of Appendix 6, of the International Passamaquoddy Engineering Board's report, dated October 1959. It was assumed that the runoff from the local area of 101 square miles would follow the same pattern. Therefore, the ordinates of the hydrograph were increased by the ratio of the drainage areas to represent the runoff from the lower-Allagash-plus-local drainage area of 641 square miles.

During the design flood, the spillway would be operated so as to reregulate the flow from the Dickey powerhouse as shown on Plate No. 10. The average flow from the Dickey powerhouse would be 6,225 c.f.s. The regulated outflow would be equal to the sum of flood inflows plus this amount as shown by the dashed line. The pool elevation would vary between 602.5 and 605.0, as shown.

The spillway would consist of an approach channel, a control structure, a chute, a stilling basin and a discharge channel as shown on Plate No. 9.

The control structure would be a gated spillway having four 30- by 40-foot Taintor gates. Its discharge capacity would be 100,000 c.f.s. at full pool, which is 8 percent more than spillway design discharge.

The chute would have a relatively level grade for a distance of about 250 feet, on which velocities would be faster than critical. This length was selected for economy of excavation. The flat chute would be followed by a steep chute down into the stilling basin.

The stilling basin would be designed to produce a hydraulic jump to safely dissipate the energy of the water. It would be provided with two rows of baffle blocks and an end sill to stabilize the jump. An excavated channel would convey spillway discharges back to the Saint John River.

5-07 POWERHOUSE

The powerhouse would be integral with the intake structure and would be located on the left bank of the river in an excavated channel as shown on Plate No. 9.

The generalproject considerations, previously described, established the minimum net head as 56 feet, rated net head as 61 feet, and the maximum net head as 67 feet. The plant dependable capacity of 34,000 kilowatts would be required at the minimum net head of 56 feet with the turbines operating at full gate. The plant was sized on the basis of the regulated flow of 4,570 c.f.s. and a 60 percent load factor. Preliminary studies made by I.J.C. for Kaplan and fixed-blade propeller-type turbines in 1-, 2-, and 3-unit plants indicated that a 2-unit plant with Kaplan type turbines would be most favorable. Each of the two turbines would be rated at 25,900 h.p. at full gate, with a head of 61 feet and a speed of 138.5 r.p.m. Each generator would be rated at 90 percent power factor, a 60°C rise at 18,900 kv.-a. and an 80°C rise at 21,700 kv.-a.

The powerhouse would be of the indoor type. Units would be on 55-foot centers with a 70-foot assembly and station service area provided at the southeast end of the plant. Access level would be at elevation 550, which provides a freeboard of 5 feet above spillway design flood tailwater. The one main power transformer would be located on the tailrace deck, elevation 550. Generators would be located at elevation 560. Scroll case and draft tube access galleries would be provided at elevations 533 and 516.5 respectively. The scroll case would be of formed concrete with centerline at elevation 537.

Conventional mechanical equipment and electrical systems normally included in powerhouses of this type would be provided. One, 3-phase, 43,400 kv.-a. transformer would serve both generators through 13.8 kv. air circuit breakers. The transformer would be connected to the 230,000-volt transmission line through a conventional switchyard. Governors and switchboards would be located between the units at elevation 560. This area would serve as the station control room. Station service power supply would be from two transformers connected to terminals of the generators.

5-08 ROAD NETS

Construction of the Lincoln School project will include some changes to existing roads, as follows:

Access to timberlands east of Little Black River, blocked by the Dickey reservoir, would be provided by a road on top of Lincoln School Dam to the north side of Saint John River and thence to the proposed Falls Brook dike, as shown on Plate No. 9. Access to the powerhouse is by service road from Highway 161 to the south end where the maintenance area is located.

Portions of State Route 161 between Lincoln School and the Dickey damsite, which would be inundated by the Lincoln School reservoir, would be relocated on higher ground as shown on Plate No. 5. THe power pole line of the Maine Public Service Company and the Fort Kent Telephone Company pole line would require relocation along with Highway 161.

5-09 LANDS AND DAMAGES

In addition to the land acquired for the Dickey Dam work area, there are about 2,150 acres of land and improvements that would be required at elevation 605, plus a 300-foot buffer and access strip. The estimate for the acquisition of this land is in the cost schedule of Lincoln School. A logway is provided at the Lincoln School Dam to provide for passage of timber and pulpwood.

5-10 SERVICE FACILITIES

Joint service facilities will be provided for the Dickey and Lincoln School projects and would be located at Dickey.

5-11 OPERATION AND MAINTENANCE

The operating staff at Dickey would be responsible for the operation and maintenance of Lincoln School.

5-12 CONSTRUCTION SCHEDULE

Construction of the Lincoln School project would begin after the Dickey Dam had been raised to sufficient height to control flows from the Saint John River. Sequence of construction is shown on Schedule 3 accompanying Chapter IV of this report.

CHAPTER VI

FLOOD CONTROL AND RECREATION

6-01 FLOOD CONTROL ON SAINT JOHN RIVER

Snowmelt, sometimes in combination with rainfall, annually produce spring floods along the Saint John River. The area, being sparsely settled, has not been exposed to significant damages with the exception of Fort Kent located about twenty-eight miles downstream of the Dickey Dam. The Fort Kent urban area has experienced seven consequential floods during the past 36 years of record. Two of the largest floods have occurred within the past five years, the most damaging being in 1961 a recurrence of which would cause damages at today's prices of $450,000.

Damages at Fort Kent start at a river discharge of 100,000 c.f.s. The 1961 discharge was 131,000 c.f.s. Inasmuch as the Dickey Dam controls 47.5% of the contributing drainage areas, impoundment of flood waters would reduce discharges to well below the zero damage stage.

The alternate method for prevention of damages, without reservoirs, would be by a local protection project. A recent study investigation by the New England Division, Corps of Engineers in 1963 indicated that such a project would cost $1,060,000. Dickey Dam makes such a project unnecessary and results in average annual benefits at Fort Kent of $40,000.

6-02 INCIDENTAL CONSTRUCTION FOR RECREATION

Plans for construction of facilities at the Passamaquoddy project for the convenience of visitors are as follows:

A parking area for visitors would be provided at Powerhouse No. 1. A parking area and picnic grounds would be provided at Carlow Island. A visitors gallery and exhibit area would be provided in the tidal powerhouses. The service roads to the tidal dams, locks, and gates could be used by visitors to obtain an over-all view of the tidal project. It is expected that sightseeing tours would be conducted by suitable members of the operating staff.

Plans for recreation facilities at the Dickey reservoir consist of a camping area and boat-launching ramps. They would be located on the east side of the Campbell Brook arm of the Dickey reservoir adjacent to the proposed ferry landing as shown on Plate No. 5. The 30-acre camping area would be cleared of underbrush, campsites laid out, gravel roads constructed, and toilet and water provided. A ramp for small boats would be constructed. Access to the area would be provided by a new road about 2.7 miles long which would connect to the existing roads along the Allagash River. Picnic areas will be scattered throughout the reservoir.

6-03 TIDAL PLANT FISHWAYS

Plans of the tidal powerhouses, Plate Nos. 1, 2, and 3, indicate fishways to provide for the passage of eastern salmon, shad and alewives.

This is in accordance with the desires of the authorities interested in sport fishing and wildlife. The fish ladders and collection galleries are similar to those shown in the I.J.C. report.

CHAPTER VII

COST ESTIMATES

7-01 GENERAL

This chapter covers the estimates of cost, as of January 1964, of the Passamaquoddy Tidal Power Project together with the proposed hydroelectric auxiliary plant on the Saint John River at Dickey, Maine. The layout and design of the tidal project remains the same as proposed in the 1959 report to the International Joint Commission with the exception of the powerplant, which is based on the use of inclined turbines and generators instead of the vertical type. The powerplant proposed in 1959 comprised thirty 10,000 kw. units for a total installed capacity of 300,000 kw. In this report four sizes of powerplants are proposed for study, namely thirty, fifty, seventy and one hundred units of 10,000 kw. each, with the thirty or fifty units located in Powerhouse No. 1 and the additional capacities to make up the seventy or one hundred units in Powerhouse No. 2.

The proposed dam at Dickey, together with the reregulating dam at Lincoln School, comprise new layouts as required by the concept of developing peaking power and the preservation of the Allagash River as a white-water recreational area.

7-02 BASIS OF ESTIMATES

The estimates herein have been prepared to provide usability in economic analysis of the ultimate plan of development and incremental units thereof.

Four separate estimates have been prepared for the Passamaquoddy Tidal Power Project. The dams, gates, and navigation locks are common to each and are therefore the same in each, except for amount of excavation available for dams. The variation is applicable to the powerplant and the headrace and tailrace required.

At Dickey there are four separate estimates based on installations of 190, 380, 475, and 760 megawatt installations. The estimate for the 190 mw. installation includes the dam, outlet works, spillway, closure dikes, the powerhouse for the ultimate development of 760, but the installation of only two turbines and generators (2 @ 95 mw.) together with two penstocks and necessary auxiliary equipment. The variation of the other estimates results from the incremental addition of subsequent turbines and generators to the base installation.

The Lincoln School estimate is predicated on total construction at one time.

7-03 CRITERIA FOR UNIT COSTS

Unit costs that make up the various elements for the project have been developed on current construction knowledge and information. The unit costs used in the I.J.C. report of 1961 developed from detailed research have been carefully reviewed and have been utilized as far as possible subject to necessary adjustments due to changes in the costs of equipment, materials and of rates of wages, as well as in the continuing economy of more efficient construction machinery and methods of construction operations.

The labor rates used as a basis for the cost estimates are the rates that it is believed a contractor would be required to pay even though they may be higher than prevailing rates of wages in the localities. A typical list of such wages are listed in Appendix II, Table 1.

Ownership rates of construction equipment have been revalued based on a long service concept on large projects. Typical rates of land and marine equipment are listed in Appendix II, Table 2.

7-04 PROJECT FEATURES

The designs of the tidal plant remain the same as in the 1961 I.J.C. report except for the powerplant which is based on the concept of inclined turbines and generators. However, since the amount of excavated rock for the proposed powerplants will vary from the 30-unit plant in the I.J.C. report, the costs of the tidal barriers will be changed due to the necessity of having more usable rock and thus requiring less material from expensive borrow areas.

Materials obtainable at the proposed Dickey damsite are somewhat different from those found at the I.J.C. report location of Rankin Rapids. Sources of materials for the dam are based on an average haul of 2-1/2 miles; concrete aggregates as well as select armor stone are to come from Deboullie Mountain, a distance of about 18 miles, and imported materials and equipment are expected to arrive by rail to Saint Francis and thence by restrengthened highway to the site.

7-05 CONTINGENCY ALLOWANCE

An allowance for contingencies is commonly made in estimating project costs to allow for unforeseen conditions that may arise during the construction. The uncertainty about site conditions is greater than the variation in quoted prices for equipment from manufacturers. For installed equipment items, the allowance is carried at 10%. For all remaining construction items, the contingency allowance is carried at 15%. The percentage is applied to the sum of direct, indirect, distributive and overhead costs.

7-06 GOVERNMENT COSTS

The allowance for government costs which cover engineering, design, supervision, inspection and administration, have been increased from that used in the I.J.C. report, which was a straight 9%. A study of major government contracts for similar type projects indicate a higher average cost. This allowance, therefore, has been increased to 12%, except for the costs of powerplants where the allowance will remain at 9%. This 9% is being used on these structures due to the repetitive nature of the work of design which should show a saving in the cost. The percentage for government costs is applied to the sum of the construction costs and contingencies.

7-07 TIDAL POWER PROJECT

The estimate that follows is made up by computation of costs based on present day unit prices applied to the quantity surveys.

The estimate contemplates the use of excavated materials to the maximum extent possible. Further breakdown is given in Tables 3 to 6 of Appendix II. It will be noted that the construction schedule indicated in Chapter III is essentially the same as the one in the I.J.C. report of 1961. The description of construction operations by features is also the same as in the I.J.C. report. Necessary changes and additions to all features are made as entailed by the larger number of units. Powerhouse No. 1 includes the 300 mw. and 500 mw. plants and Powerhouse No. 2 the additional units for a total of 700 mw. and 1,000 mw. installation. As it is contemplated that Powerhouse No. 2 will be a later stage of construction, the excavation therefrom has been wasted. In the estimates that follow the main power transformers are included in the powerhouse costs and have been deducted from switchyard costs supplied by the Department of the Interior. Separate estimates are given for the various sizes of powerhouse in Appendix II, Tables 3 to 6. The project features that are common to all sizes of powerhouse are estimated in Appendix II, Tables 7-19 inclusive. Those common feature items that vary somewhat because of powerhouse size are given for a 500-mw. plant, they are Table 14, Dams; Table 16, Fishways; Table 17, Service Facilities; Table 18, Relocations and Table 19, Lands and Damages. The increase or decrease from the 500-mw. plant is included in the cost estimate for the various sizes of project powerhouse.

ESTIMATE OF COST

TIDAL POWER PROJECT

Item	Cost in Thousands Installed Capacities 300-MW	500-MW	700-MW	1,000-MW
Powerplant	$119,189	$204,491	$302,287	$427,162
Switchyard	1,780	2,370	3,160	3,950
Filling Gates	62,634	62,634	62,634	62,634
Emptying Gates	57,627	57,627	57,627	57,627
Locks	18,917	18,917	18,917	18,917
Dams	77,309	63,664	64,454	64,454
Lubec Channel	634	634	634	634
Fishways	888	1,298	1,748	2,324
Service Facilities	1,670	1,870	2,070	2,470
Relocations	3,929	4,931	7,431	9,631
Lands and Damages	1,870	1,870	1,960	2,030
Subtotal	$346,447	$420,306	$522,922	$651,833
Contingencies	49,520	58,967	72,728	89,616
Subtotal	$395,967	$479,273	$595,650	$741,449
Engr., Design, Supervision & Administration	43,478	50,581	61,221	74,482
TOTAL FIRST COST	$439,445	$529,854	$656,871	$815,931

7-08 DICKEY PROJECT

a. General.

The dam and powerplant at Dickey are generally of a conventional river hydroelectric pattern. The construction is adapted to the terrain making full use of natural materials available locally. Access is by Maine State Highway Route No. 161 which would terminate at the project site. Areas for the contractor's work area would be on the right bank of the Saint John River above the Allagash River. The real estate included in the project costs would provide ample area for warehouses, garage, shops and minimum housing for Government operators and maintenance staff.

b. Reservoir Clearing.

There are about 81,000 acres of forested land within the Dickey and Lincoln School reservoir area. The present estimated value of standing wood growth is approximately the full value of the woodland area. The residual land value is low. If the timberland acquisition is completed in the first part of the construction period, then the full standing value of the wood growth would be realized and would be sufficient to cancel cost of reservoir clearing. In the actual work, there may be scheduling difficulties that would prevent full realization of the standing growth value, or the timber may be cut off by owners, which would reduce the cost of the land but leave a clearing operation necessary. A sum is carried in the estimates for clearing which reflects reduction for the standing wood growth.

c. <u>Estimate of Cost.</u>

The detailed estimate of cost is shown in Appendix II, Table 20. It is based on the initial development of 2 - 95,000 kw. units. The switchyard costs furnished by the Department of the Interior are reduced by the estimate for main transformers, which are included with the powerhouse costs. The Department of the Interior requested that the construction cost estimate provide for the ultimate development of 8 units, but further, that the cost of building the powerplant in increments of 2, 4, 5 units be shown in the estimate. Accordingly, the cost by increments is provided.

ESTIMATE OF COST

DICKEY PROJECT

	Cost in Thousands			
	Installed Capacity			
Item	190-MW	380-MW	475-MW	760-MW
Lands and Damages	$ 4,469	$ 4,469	$4,469	$4,469
Relocations	1,363	1,363	1,363	1,363
Reservoir Clearing	2,000	2,000	2,000	2,000
Dams	72,919	72,919	72,919	72,919
Penstocks	3,624	7,249	9,062	14,503
Powerplant	28,531	39,093	44,591	60,229
Switchyard	1,583	1,940	2,787	3,466
Buildings, Grounds & Facilities	560	560	560	560
Access Roads	728	728	728	728
Subtotal	$115,777	$130,321	$138,479	$160,237
Contingencies	16,935	18,691	19,700	22,321
Subtotal	$132,712	$149,012	$158,179	$182,558
Engineering, design, supervision and administration	14,954	16,559	17,476	19,880
PROJECT FIRST COST	$147,666	$165,571	$175,655	$202,438

7-09 LINCOLN SCHOOL PROJECT

The Lincoln School reregulating dam would be built during the latter part of the construction period of the Dickey Dam. It would be started when the dam at Dickey is high enough to control river flow. The estimate for Lincoln School is given below:

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Cost in Thousands
Lands and Damages	$ 400
Relocations	1,238
Reservoir Clearing	40
Dams	4,323
Powerplant	6,290
Switchyard	387
Buildings, Grounds and Facilities	208
Access Roads	50
Subtotal	$12,936
Contingencies	1,776
Subtotal	$14,712
Engineering, Design, Supervision and Administration	1,553
PROJECT FIRST COST	$16,265

7-10 ANNUAL MAINTENANCE AND OPERATION COSTS

The yearly operation and maintenance costs for the Tidal Project are estimated as follows:

300 mw	500 mw	700 mw	1,000 mw
$1,126,000	$1,340,000	$1,540,000	$1,910,000

The yearly operation and maintenance costs for the Dickey and Lincoln School Projects combined are estimated to be:

	190 mw	380 mw	475 mw	760 mw
For units at Dickey	$400,000	$580,000	$670,000	$940,000

Lincoln School Project would be an automatic station and be operated and maintained from Dickey.

7-11 ANNUAL COST OF MAJOR REPLACEMENTS

The estimated cost of yearly replacements is computed assuming that about 25% of the major equipment will be replaced every 30 years.

Tidal Project

300 mw	500 mw	700 mw	1,000 mw
$333,000	$508,000	$693,000	$970,000

Dickey Project

190 mw	380 mw	475 mw	760 mw
$38,100	$74,200	$92,000	$145,000

Lincoln School Project

34 mw
$12,800

7-12 INTEREST DURING CONSTRUCTION

As requested by the Department of the Interior a brief analysis was made of the proposed construction schedules to determine the approximate amount of funds needed per year to prosecute the work. Based on the interest rate of 3% the total interest required during the construction period is given below.

Tidal Power Project

300 mw	500 mw	700 mw	1,000 mw
$33,225,000	$39,267,000	$45,966,000	$53,824,000

Upper Saint John River Development

Dickey Project

190 mw	380 mw	475 mw	760 mw
$6,500,000	$7,036,000	$7,337,000	$8,128,000

Lincoln School Project

34 mw
$480,000

7-13 ADDED COST ESTIMATE IF TURBINE HUB IS LOWERED 5 FEET FOR REVERSE PUMPING

It should be noted that when the turbines and water passages of the tidal power units are lowered 5 feet, the sidewalls of the draft tube of the power units would be increased from 6'-0" to 6'-6" making the spacing of units 63'-0" in the tidal powerhouse. The estimates are for lowering all 50 units of one tidal powerhouse. These estimates are to be added to powerhouse estimate given elsewhere in this report, if pumping is selected for operation.

The following estimate is based on using the draft tube gate guides for the trashracks. A trashrack in three sections would be provided for each opening. The racks would be stored in an enlarged slot over each opening and would be placed in the draft tube openings each time the units are pumping.

Excavation	440,000	c.y.	1.90	$ 836,000
Concrete, lowering main powerhouse	45,000	c.y.	49.00	2,205,000
Concrete, extend powerhouse to provide rack slots	27,000	c.y.	49.00	1,323,000
Trashracks (100) ea.			L.S.	1,700,000
Draft Tube Gantry Cranes (2)			L.S.	120,000
Dogging Devices			L.S.	30,000
Grating			L.S.	100,000
Machinery Modification (4%)				2,987,000
Subtotal				$ 9,301,000
Contingencies				1,395,000
				$10,696,000
Engineering, design, superv. & admin.				1,284,000
TOTAL ADDED FIRST COST				$11,980,000

7-13 ADDED COST ESTIMATE IF TURBINE HUB IS LOWERED 5 FEET FOR REVERSE PUMPING (cont'd)

Interest during construction is estimated to be $900,000 which added to the construction first cost would give a total added investment cost of $12,880,000.

The yearly added cost of operation, maintenance and replacements for one 50-unit tidal powerhouse is estimated to be $62,350.

Automatic lifting and lowering devices for trashracks would be investigated during the design stage of the project. Further investigation of riparian damages would also be necessary if reverse pumping maintains a high elevation upper pool and a low elevation lower pool for a period of one to several days, since holding of water levels might affect daily business activities.

SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

ENGINEERING REPORT

DRAWINGS

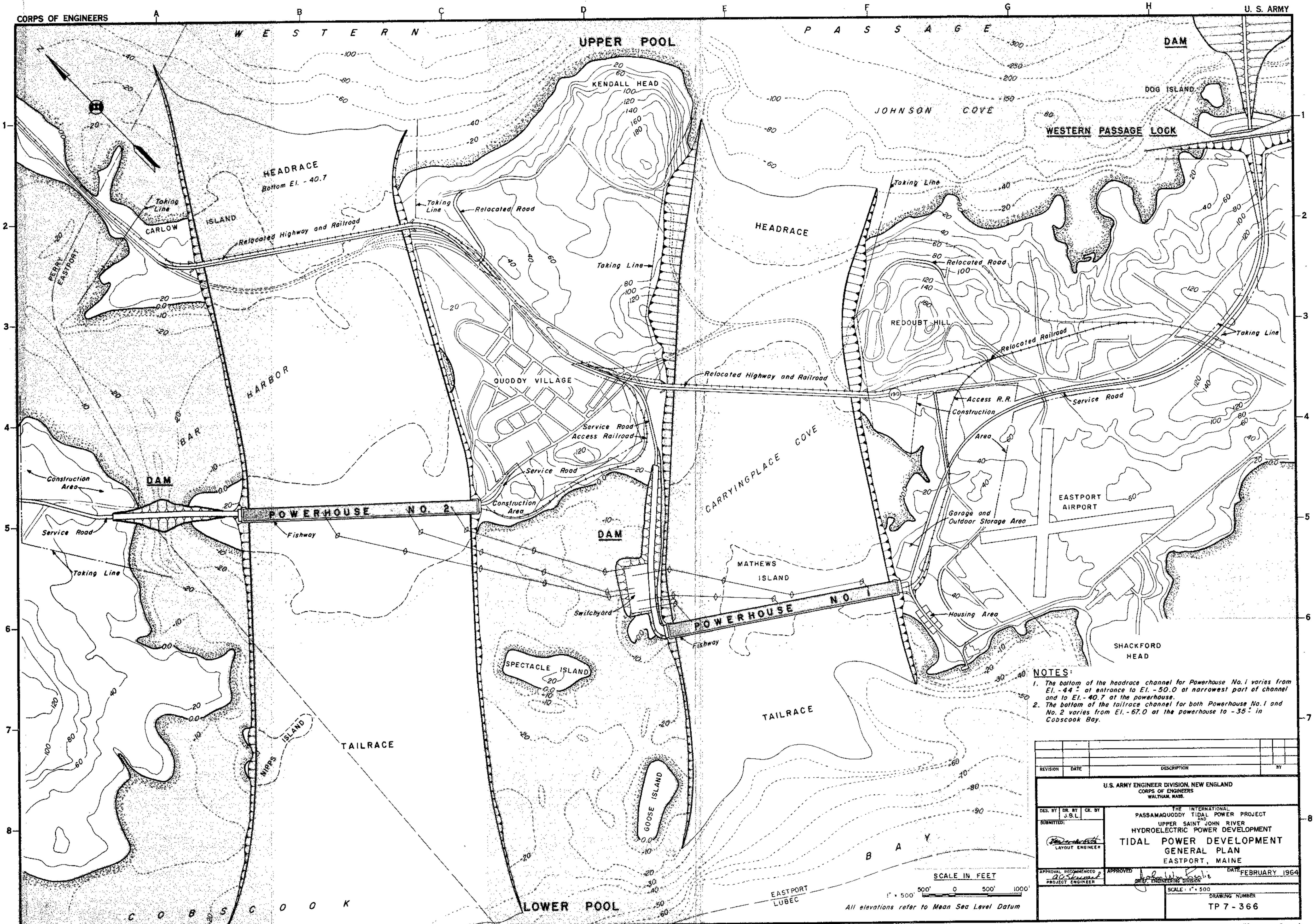
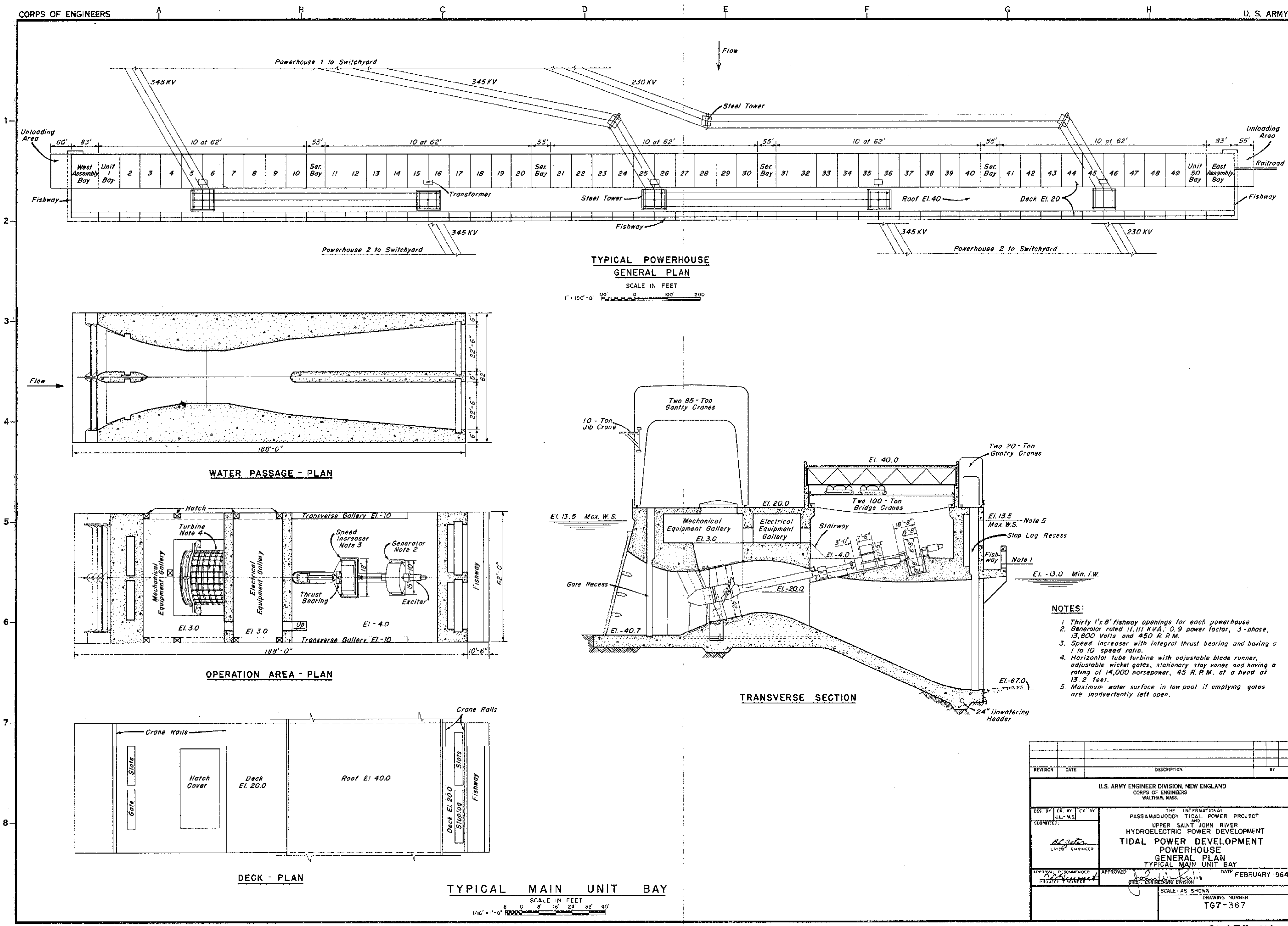

CORPS OF ENGINEERS
U. S. ARMY
WESTERN PASSAGE
UPPER POOL
DAM
KENDALL HEAD
DOG ISLAND
JOHNSON COVE
WESTERN PASSAGE LOCK
HEADRACE
Bottom El. - 40.7
CARLOW ISLAND
PERRY
EASTPORT
Taking Line
Relocated Highway and Railroad
Relocated Road
HEADRACE
Relocated Road
REDOUBT HILL
Relocated Railroad
Taking Line
QUODDY VILLAGE
Relocated Highway and Railroad
Access R.R.
Construction
Service Road
HARBOR
BAR
Service Road
Access Railroad
Service Road
Area
CARRYINGPLACE COVE
EASTPORT AIRPORT
Construction Area
DAM
POWERHOUSE NO. 2
Construction Area
Garage and Outdoor Storage Area
Service Road
Fishway
DAM
Taking Line
MATHEWS ISLAND
POWERHOUSE NO. 1
Switchyard
Housing Area
Fishway
SPECTACLE ISLAND
SHACKFORD HEAD
NIPPS ISLAND
TAILRACE
TAILRACE
GOOSE ISLAND
BAY
SCALE IN FEET
1" = 500'
All elevations refer to Mean Sea Level Datum
EASTPORT
LUBEC
COBSCOOK
LOWER POOL
NOTES:
1. The bottom of the headrace channel for Powerhouse No. 1 varies from El. -44± at entrance to El. -50.0 at narrowest part of channel and to El. -40.7 at the powerhouse.
2. The bottom of the tailrace channel for both Powerhouse No. 1 and No. 2 varies from El. -67.0 at the powerhouse to -35± in Cobscook Bay.
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY
DR. BY J.B.L.
CK. BY
SUBMITTED:
LAYOUT ENGINEER
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
TIDAL POWER DEVELOPMENT
GENERAL PLAN
EASTPORT, MAINE
APPROVAL RECOMMENDED
PROJECT ENGINEER
APPROVED
CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE: 1" = 500
DRAWING NUMBER
TP 7-366

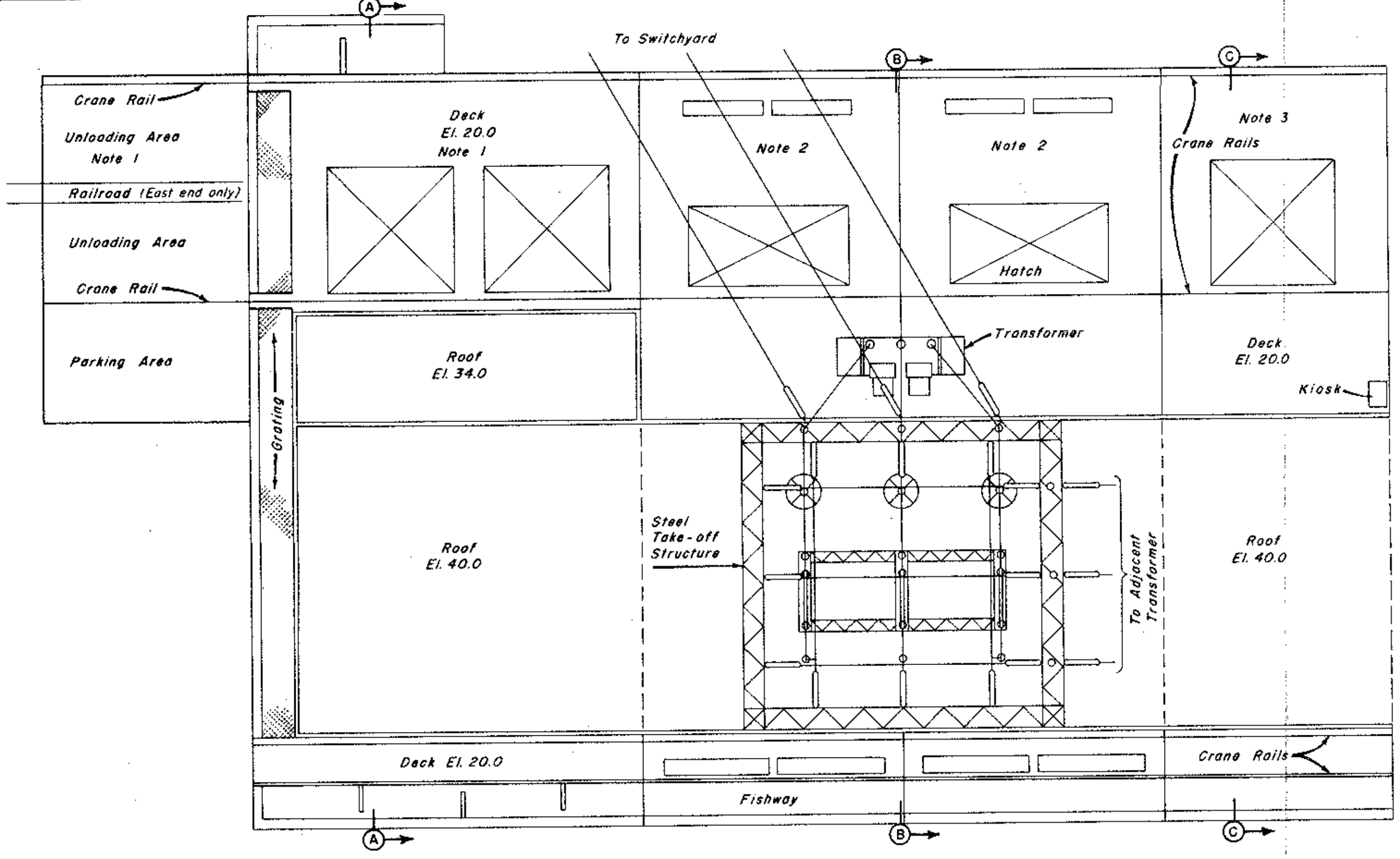
PLATE NO. 1



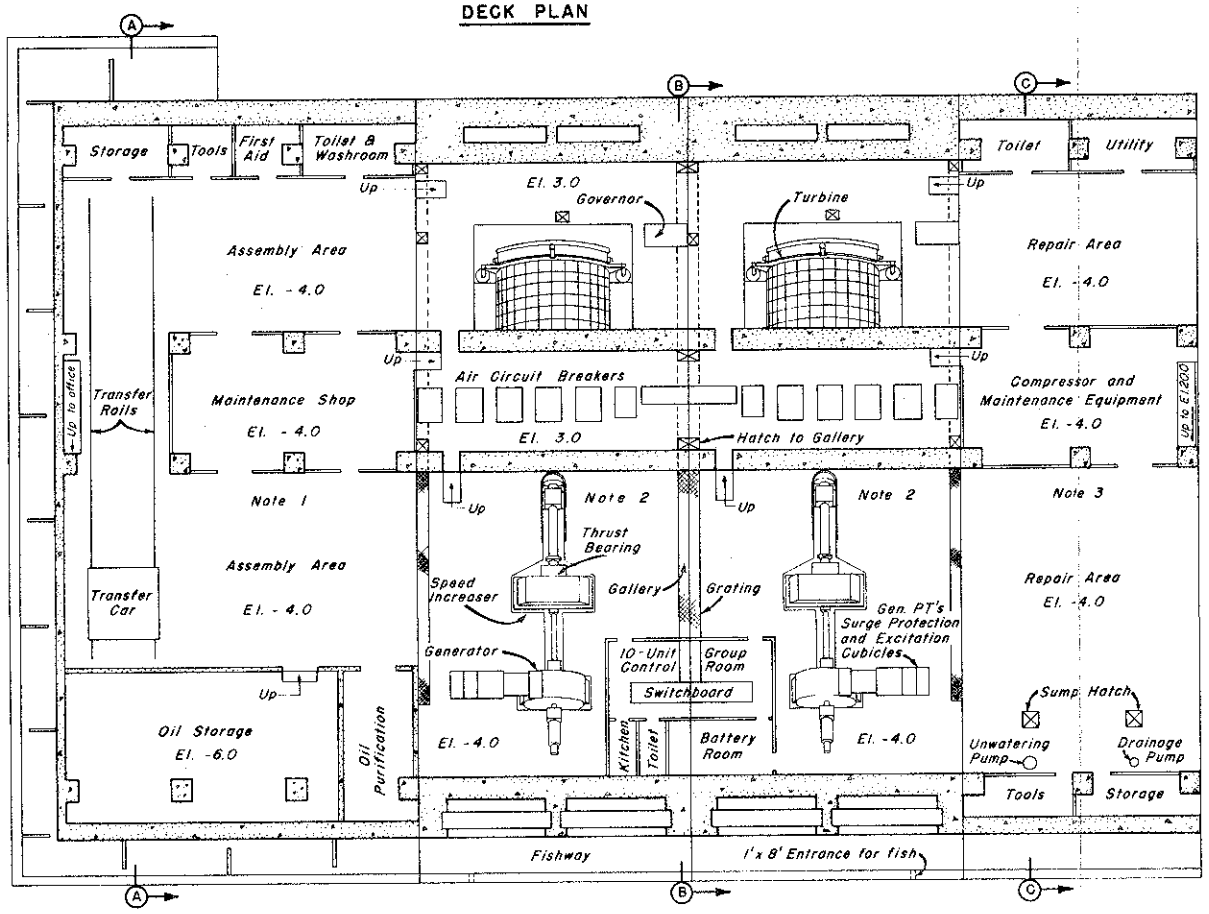
CORPS OF ENGINEERS
U. S. ARMY
Flow
Powerhouse 1 to Switchyard
345 KV
345 KV
230 KV
Steel Tower
Unloading Area
60'
83'
10 at 62'
55'
West Assembly Bay
Unit 1 Bay
Ser. Bay
Unit 50 Bay
East Assembly Bay
Railroad
Fishway
Transformer
Steel Tower
Roof El. 40
Deck El. 20
Powerhouse 2 to Switchyard
TYPICAL POWERHOUSE
GENERAL PLAN
SCALE IN FEET
1" = 100'-0"
Flow
188'-0"
62'
22'-6"
WATER PASSAGE - PLAN
Hatch
Transverse Gallery El. -10
Turbine Note 4
Speed Increaser Note 3
Generator Note 2
Mechanical Equipment Gallery
Electrical Equipment Gallery
Thrust Bearing
Exciter
Fishway
El. 3.0
El. 3.0
El - 4.0
Up
62'-0"
188'-0"
10'-6"
OPERATION AREA - PLAN
Crane Rails
Slots
Gate
Hatch Cover
Deck El. 20.0
Roof El 40.0
Deck El 20.0
Stoplog
Fishway
DECK - PLAN
TYPICAL MAIN UNIT BAY
SCALE IN FEET
1/16" = 1'-0"
Two 85 - Ton Gantry Cranes
10 - Ton Jib Crane
Two 20 - Ton Gantry Cranes
El. 40.0
El. 20.0
Two 100 - Ton Bridge Cranes
El. 13.5 Max. W. S.
Mechanical Equipment Gallery El. 3.0
Electrical Equipment Gallery
Stairway
El. -4.0
El. -20.0
El. 13.5 Max. W.S.
Note 5
Stop Log Recess
Fishway
Note 1
El. -13.0 Min. T.W.
Gate Recess
El. -40.7
El. -67.0
24" Unwatering Header
TRANSVERSE SECTION
NOTES:
1. Thirty 1'x8' fishway openings for each powerhouse.
2. Generator rated 11,111 KVA, 0.9 power factor, 3-phase, 13,800 Volts and 450 R.P.M.
3. Speed increaser with integral thrust bearing and having a 1 to 10 speed ratio.
4. Horizontal tube turbine with adjustable blade runner, adjustable wicket gates, stationary stay vanes and having a rating of 14,000 horsepower, 45 R.P.M. at a head of 13.2 feet.
5. Maximum water surface in low pool if emptying gates are inadvertently left open.
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
TIDAL POWER DEVELOPMENT
POWERHOUSE
GENERAL PLAN
TYPICAL MAIN UNIT BAY
LAYOUT ENGINEER
PROJECT ENGINEER
CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE: AS SHOWN
DRAWING NUMBER
TG7-367

PLATE NO. 2

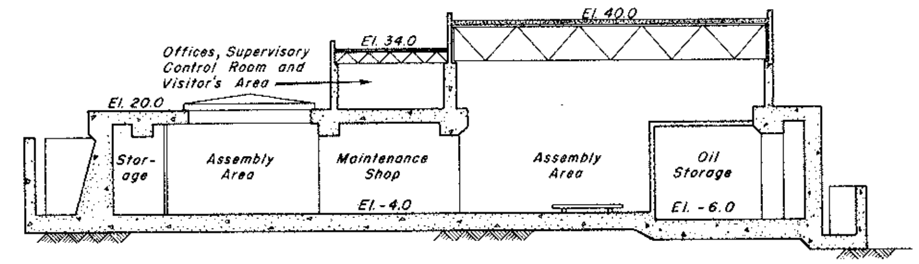
CORPS OF ENGINEERS | U. S. ARMY



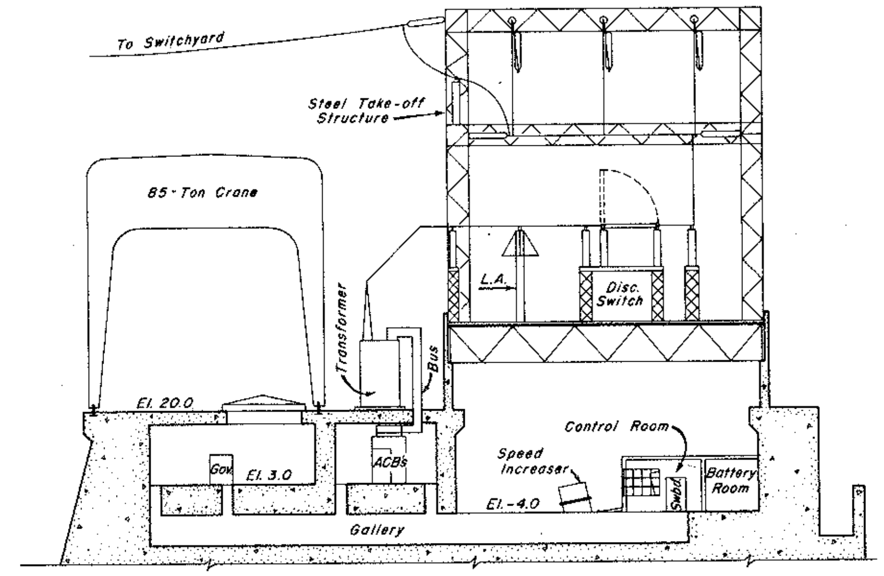
DECK PLAN



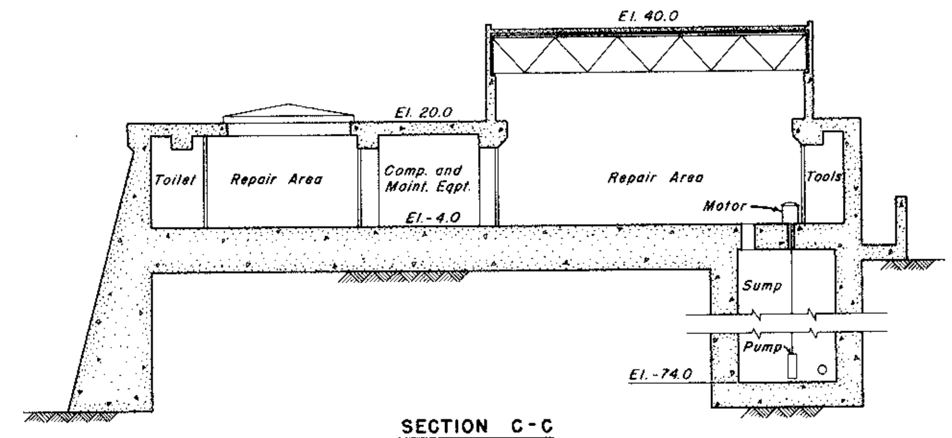
OPERATING FLOOR PLAN



SECTION A-A



SECTION B-B



SECTION C-C

SCALE IN FEET

1/16" = 1'-0" 8' 0 8' 16' 24' 32' 40'

NOTES:

1. Typical assembly bay except opposite hand for east end.
2. Typical main unit bay except that take-off structure, transformer, air circuit breakers and 10-unit group control area occur only at middle of each of 5 groups of 10-units.
3. Typical service bay that occurs between each group of 10-units.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY M.S.-J.L. | CK. BY

SUBMITTED: LAYOUT ENGINEER

THE INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT
TIDAL POWER DEVELOPMENT
POWERHOUSE
GENERAL ARRANGEMENT

APPROVAL RECOMMENDED: PROJECT ENGINEER

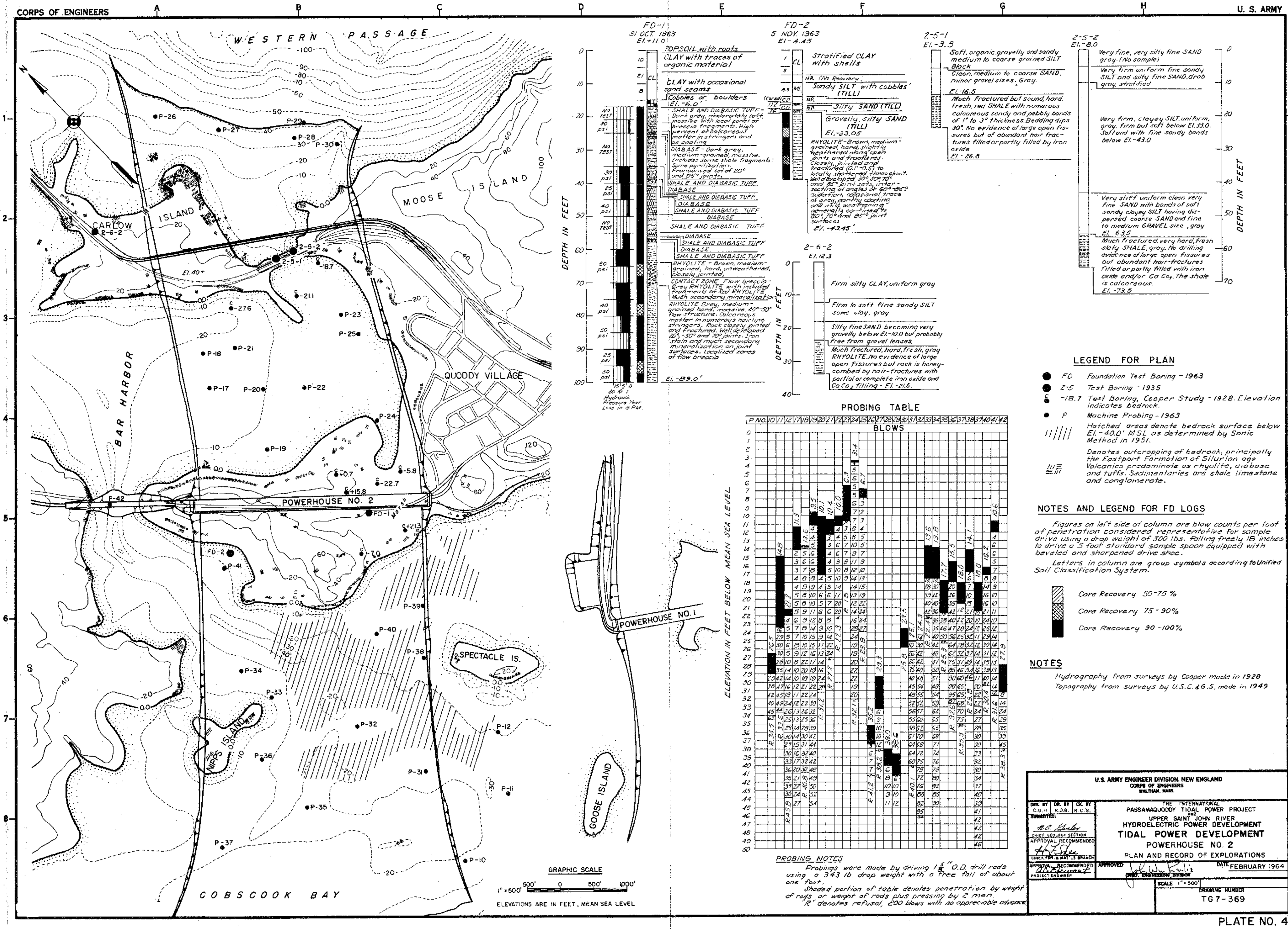
APPROVED: CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

SCALE: 1/16" = 1'-0"

DRAWING NUMBER
TG7-368

PLATE NO. 3

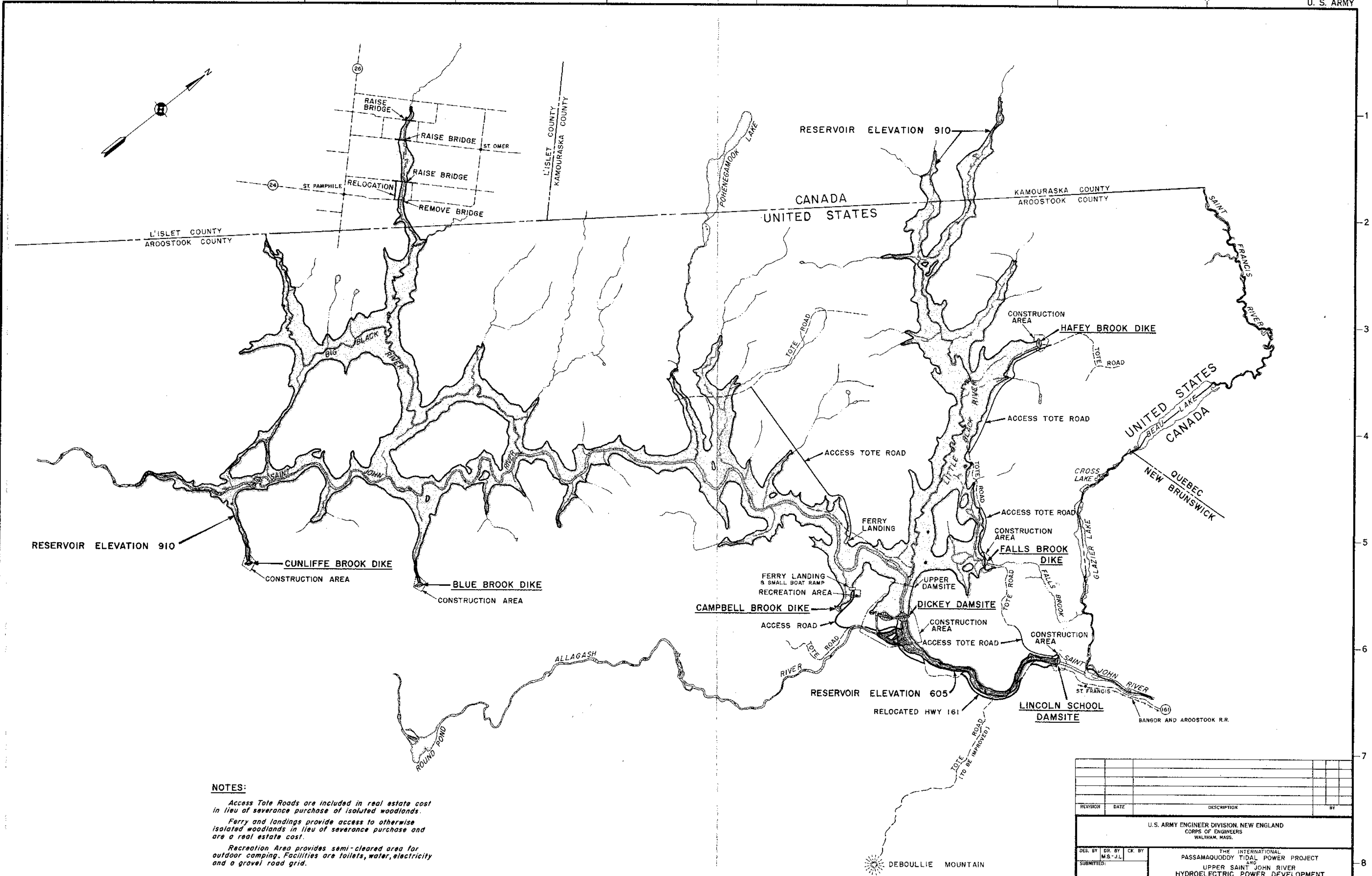


CORPS OF ENGINEERS
U. S. ARMY
WESTERN PASSAGE
CARLOW ISLAND
MOOSE ISLAND
QUODDY VILLAGE
BAR HARBOR
POWERHOUSE NO. 2
POWERHOUSE NO. 1
SPECTACLE IS.
GOOSE ISLAND
NIPPS ISLAND
COBSCOOK BAY
GRAPHIC SCALE
1" = 500'
ELEVATIONS ARE IN FEET, MEAN SEA LEVEL
FD-1
31 OCT. 1963
El. +11.0
TOPSOIL with roots
CLAY with traces of organic material
CLAY with occasional sand seams
Cobbles or boulders
El. -6.0'
SHALE AND DIABASIC TUFF - Dark grey, moderately soft, massive with local zones of breccia fragments. High percent of calcareous matter in stringers and as coating
DIABASE - Dark grey, medium-grained, massive. Includes some shale fragments. Some pyritization. Pronounced set of 20° and 85° joints.
SHALE AND DIABASIC TUFF
DIABASE
SHALE AND DIABASIC TUFF
DIABASE
SHALE AND DIABASIC TUFF
DIABASE
SHALE AND DIABASIC TUFF
DIABASE
SHALE AND DIABASIC TUFF
DIABASE
SHALE AND DIABASIC TUFF
RHYOLITE - Brown, medium-grained, hard, unweathered, closely jointed,
CONTACT ZONE Flow breccia - Grey RHYOLITE with included fragments of Red RHYOLITE. Much secondary mineralization
RHYOLITE Grey, medium-grained hard, massive, 40°-50° flow structure. Calcareous matter in numerous hairline stringers. Rock closely jointed and fractured. Well developed 20°, -50° and 70° joints. Iron stain and much secondary mineralization on joint surfaces. Localized zones of flow breccia
El. -89.0'
DEPTH IN FEET
Hydraulic Pressure Test Loss in G.P.M.
FD-2
5 NOV. 1963
El - 4.45
Stratified CLAY with shells
NR (No Recovery)
Sandy SILT with cobbles (TILL)
NR
Silty SAND (TILL)
Gravelly, silty SAND (TILL)
El. -23.05
RHYOLITE - Brown, medium-grained, hard, slightly weathered along open joints and fractures. Closely jointed and fractured (0.1'-0.5') to locally shattered throughout. Well developed 30°, 50°, 70° and 85° joint sets, intersecting at angles of 60°-85°. Oxidation, occasional trace of grey, earthy coating and mild weathering generally confined to 60°, 70° and 85° joint surfaces
El. -43.45'
2-6-2
El. 12.3
Firm silty CLAY, uniform gray
Firm to soft fine sandy SILT some clay, gray
Silty fine SAND becoming very gravelly below El. -10.0 but probably free from gravel lenses.
Much fractured, hard, fresh, gray RHYOLITE. No evidence of large open fissures but rock is honey-combed by hair-fractures with partial or complete iron oxide and CaCo3 filling - El. -21.5.
2-5-1
El. -3.3
Soft, organic gravelly and sandy medium to coarse grained SILT Black
Clean, medium to coarse SAND, minor gravel sizes. Gray.
El. -16.5
Much fractured but sound, hard, fresh, red SHALE with numerous calcareous sandy and pebbly bands of 1" to 3" thickness. Bedding dips 30°. No evidence of large open fissures but of abundant hair fractures filled or partly filled by iron oxide
El. - 26.8
2-5-2
El. -8.0
Very fine, very silty fine SAND gray. (No sample)
Very firm uniform fine sandy SILT and silty fine SAND, drab gray, stratified
Very firm, clayey SILT, uniform, gray. Firm but soft below El. 33.0. Soft and with fine sandy bands below El. -43.0
Very stiff uniform clean very fine SAND with bands of soft sandy clayey SILT having dispersed coarse SAND and fine to medium GRAVEL size, gray
El. -63.5
Much fractured, very hard, fresh slaty SHALE, gray. No drilling evidence of large open fissures but abundant hair-fractures filled or partly filled with iron oxide and/or Ca Co3. The shale is calcareous.
El. -73.5
PROBING TABLE
P NO. 10 11 12 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
BLOWS
ELEVATION IN FEET BELOW MEAN SEA LEVEL
PROBING NOTES
Probings were made by driving 1 5/8" O.D. drill rods using a 343 lb. drop weight with a free fall of about one foot.
Shaded portion of table denotes penetration by weight of rods or weight of rods plus pressing by 2 men.
"R" denotes refusal, 200 blows with no appreciable advance.
LEGEND FOR PLAN
FD Foundation Test Boring - 1963
2-5 Test Boring - 1935
-18.7 Test Boring, Cooper Study - 1928. Elevation indicates bedrock.
P Machine Probing - 1963
Hatched areas denote bedrock surface below El. -40.0' MSL as determined by Sonic Method in 1951.
Denotes outcropping of bedrock, principally the Eastport Formation of Silurian age Volcanics predominate as rhyolite, diabase and tuffs. Sedimentaries are shale limestone and conglomerate.
NOTES AND LEGEND FOR FD LOGS
Figures on left side of column are blow counts per foot of penetration considered representative for sample drive using a drop weight of 300 lbs. falling freely 18 inches to drive a 5 foot standard sample spoon equipped with beveled and sharpened drive shoe.
Letters in column are group symbols according to Unified Soil Classification System.
Core Recovery 50-75 %
Core Recovery 75 - 90%
Core Recovery 90 - 100%
NOTES
Hydrography from surveys by Cooper made in 1928
Topography from surveys by U.S.C.&G.S. made in 1949
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY C.G.H
DR. BY R.D.B.
CK. BY R.C.G.
SUBMITTED:
CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED
CHIEF, FDN. & MAT'LS BRANCH
APPROVAL RECOMMENDED
PROJECT ENGINEER
APPROVED
CHIEF, ENGINEERING DIVISION
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
TIDAL POWER DEVELOPMENT
POWERHOUSE NO. 2
PLAN AND RECORD OF EXPLORATIONS
DATE FEBRUARY 1964
SCALE 1" = 500'
DRAWING NUMBER
TG7-369

PLATE NO. 4

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

Access Tote Roads are included in real estate cost in lieu of severance purchase of isolated woodlands.

Ferry and landings provide access to otherwise isolated woodlands in lieu of severance purchase and are a real estate cost.

Recreation Area provides semi-cleared area for outdoor camping. Facilities are toilets, water, electricity and a gravel road grid.

SCALE IN THOUSAND FEET

5 0 5 10 15 20 25

SCALE: 1" = 9,250' ±

All elevations refer to Mean Sea Level Datum

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY M.S.-J.L. | CK. BY

SUBMITTED:

LAYOUT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY AND LINCOLN SCHOOL RESERVOIR MAP

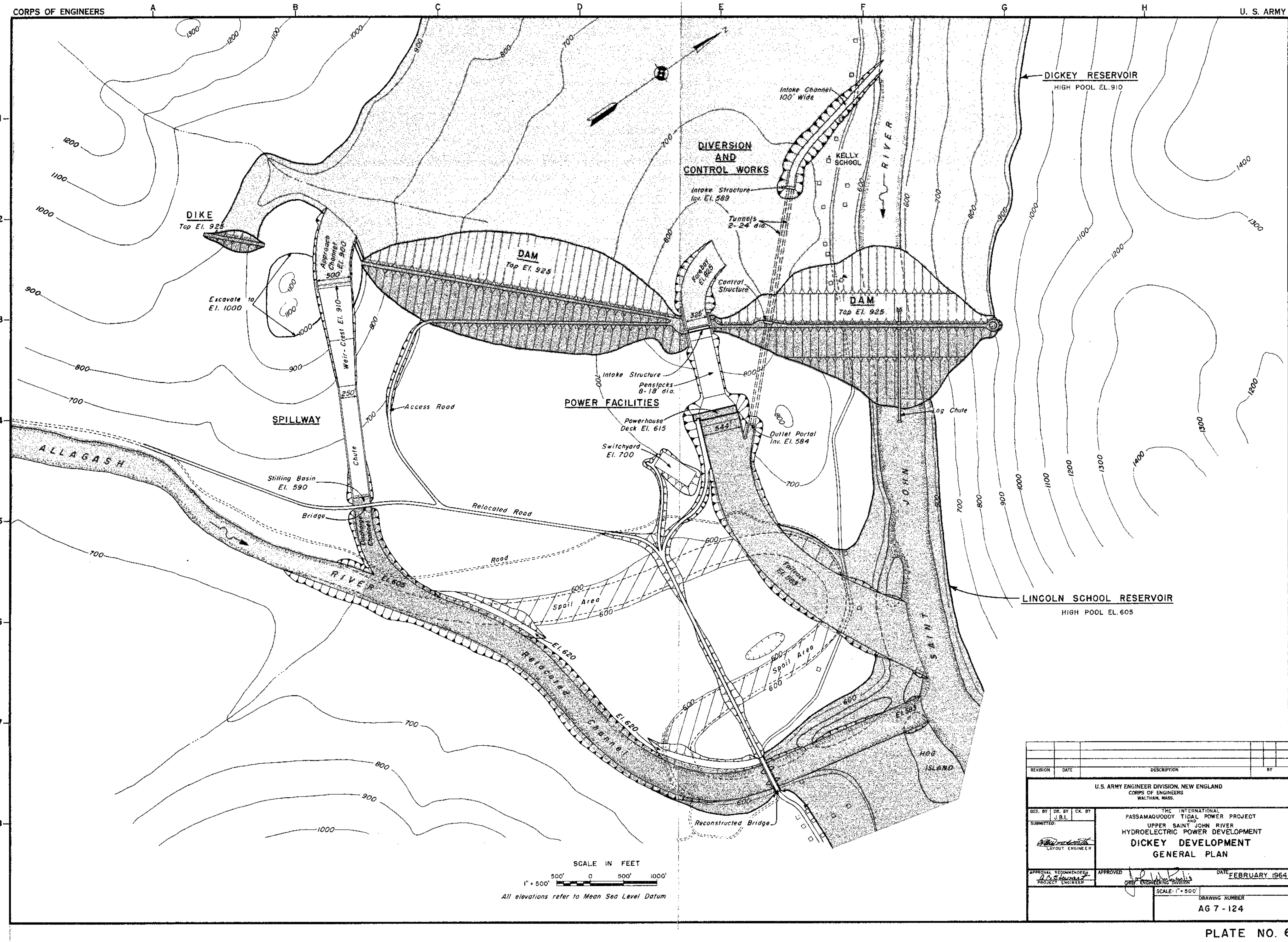
APPROVAL RECOMMENDED — PROJECT ENGINEER

APPROVED — CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

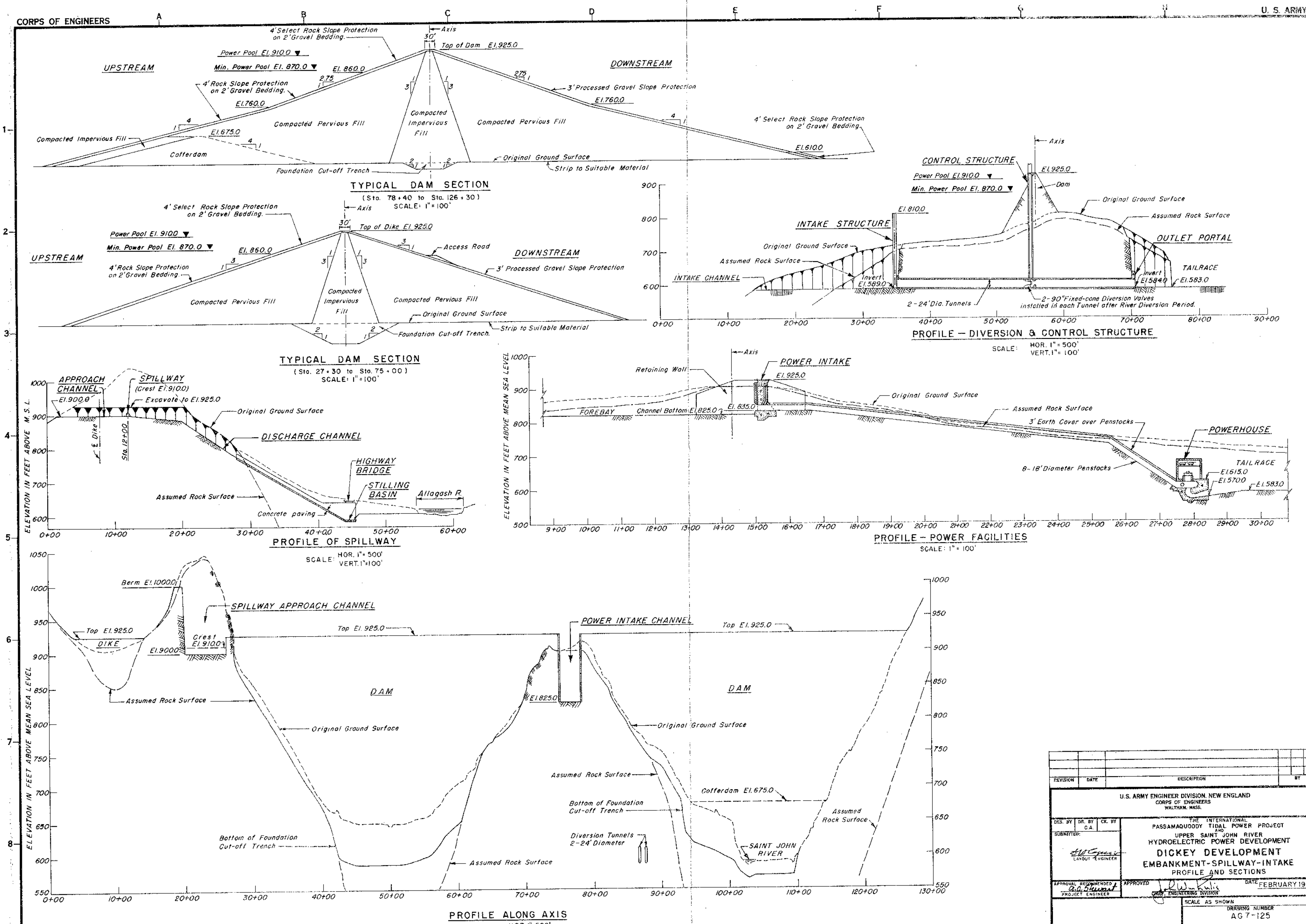
SCALE AS SHOWN

DRAWING NUMBER AG7-123



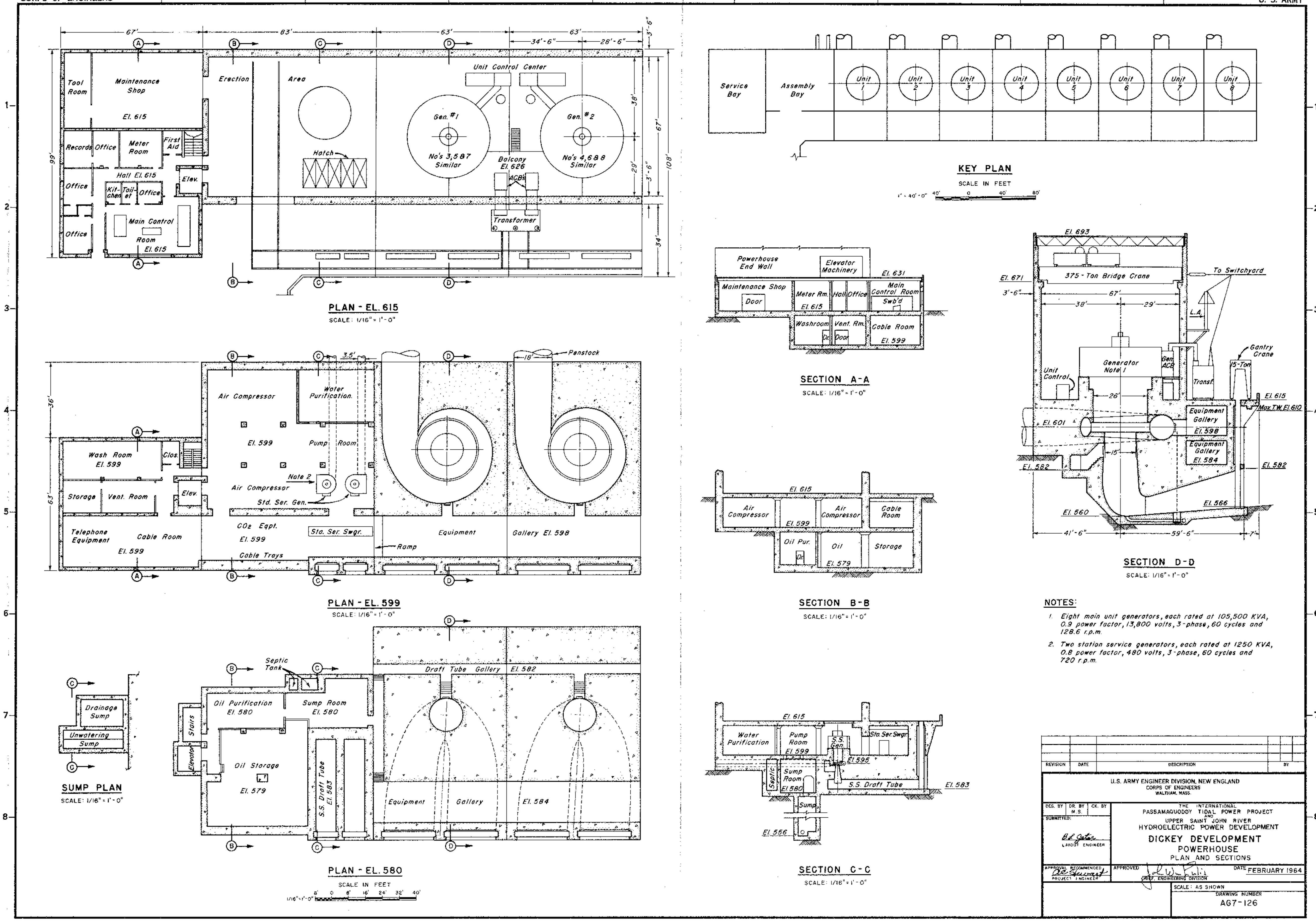
CORPS OF ENGINEERS
U. S. ARMY
DICKEY RESERVOIR
HIGH POOL EL. 910
DIVERSION AND CONTROL WORKS
Intake Channel 100' Wide
KELLY SCHOOL
Intake Structure Inv. El. 589
Tunnels 2-24' dia.
RIVER
DIKE
Top El. 925
Approach Channel El. 900
DAM
Top El. 925
Forebay El. 825
Control Structure
Excavate to El. 1000
Weir-Crest El. 910
Intake Structure
Penstocks 8-18' dia.
POWER FACILITIES
Access Road
Log Chute
Powerhouse Deck El. 615
SPILLWAY
Switchyard El. 700
Outlet Portal Inv. El. 584
ALLAGASH
Chute
Stilling Basin El. 590
Relocated Road
Bridge
Discharge Channel
Road
Tailrace El. 583
JOHN
LINCOLN SCHOOL RESERVOIR
HIGH POOL EL. 605
Spoil Area
RIVER
El. 605
El. 620
Relocated Channel
SAINT
El. 583
HOG ISLAND
Reconstructed Bridge
SCALE IN FEET
1" = 500'
All elevations refer to Mean Sea Level Datum
REVISION DATE DESCRIPTION BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY DR. BY J.B.L. CK. BY
SUBMITTED:
LAYOUT ENGINEER
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
DICKEY DEVELOPMENT
GENERAL PLAN
APPROVAL RECOMMENDED:
PROJECT ENGINEER
APPROVED
CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE: 1" = 500'
DRAWING NUMBER
AG 7-124

PLATE NO. 6



CORPS OF ENGINEERS
U. S. ARMY
UPSTREAM
DOWNSTREAM
4' Select Rock Slope Protection on 2' Gravel Bedding.
Axis
Top of Dam El. 925.0
Power Pool El. 910.0
Min. Power Pool El. 870.0
El. 860.0
4' Rock Slope Protection on 2' Gravel Bedding.
El. 760.0
El. 675.0
Compacted Impervious Fill
Cofferdam
Compacted Pervious Fill
3' Processed Gravel Slope Protection
4' Select Rock Slope Protection on 2' Gravel Bedding.
El. 610.0
Original Ground Surface
Strip to Suitable Material
Foundation Cut-off Trench
TYPICAL DAM SECTION
(Sta. 78+40 to Sta. 126+30)
SCALE: 1" = 100'
Top of Dike El. 925.0
Access Road
El. 910.0
TYPICAL DAM SECTION
(Sta. 27+30 to Sta. 75+00)
SCALE: 1" = 100'
CONTROL STRUCTURE
El. 925.0
Dam
Assumed Rock Surface
INTAKE STRUCTURE
El. 810.0
OUTLET PORTAL
TAILRACE
INTAKE CHANNEL
Invert El. 589.0
Invert El. 584.0
El. 583.0
2 - 24' Dia. Tunnels
2 - 90" Fixed-cone Diversion Valves installed in each Tunnel after River Diversion Period.
PROFILE – DIVERSION & CONTROL STRUCTURE
SCALE: HOR. 1" = 500' VERT. 1" = 100'
APPROACH CHANNEL
SPILLWAY (Crest El. 910.0)
El. 900.0
Excavate to El. 925.0
DISCHARGE CHANNEL
HIGHWAY BRIDGE
STILLING BASIN
Allagash R.
Concrete paving
ELEVATION IN FEET ABOVE M. S. L.
PROFILE OF SPILLWAY
SCALE: HOR. 1" = 500' VERT. 1" = 100'
POWER INTAKE
Retaining Wall
FOREBAY
Channel Bottom El. 825.0
El. 835.0
3' Earth Cover over Penstocks
POWERHOUSE
8 - 18' Diameter Penstocks
El. 615.0
El. 570.0
El. 583.0
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
PROFILE – POWER FACILITIES
SCALE: 1" = 100'
Berm El. 1000.0
SPILLWAY APPROACH CHANNEL
Top El. 925.0
DIKE
El. 900.0
Crest El. 910.0
POWER INTAKE CHANNEL
DAM
El. 825.0
Cofferdam El. 675.0
Bottom of Foundation Cut-off Trench
Diversion Tunnels 2-24' Diameter
SAINT JOHN RIVER
PROFILE ALONG AXIS
SCALE: HOR. 1" = 500' VERT. 1" = 50'
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
DICKEY DEVELOPMENT
EMBANKMENT-SPILLWAY-INTAKE
PROFILE AND SECTIONS
DATE FEBRUARY 1964
SCALE AS SHOWN
DRAWING NUMBER AG 7-125

PLATE NO. 7



NOTES:

1. Eight main unit generators, each rated at 105,500 KVA, 0.9 power factor, 13,800 volts, 3-phase, 60 cycles and 128.6 r.p.m.
2. Two station service generators, each rated at 1250 KVA, 0.8 power factor, 480 volts, 3-phase, 60 cycles and 720 r.p.m.

REVISION	DATE	DESCRIPTION	BY

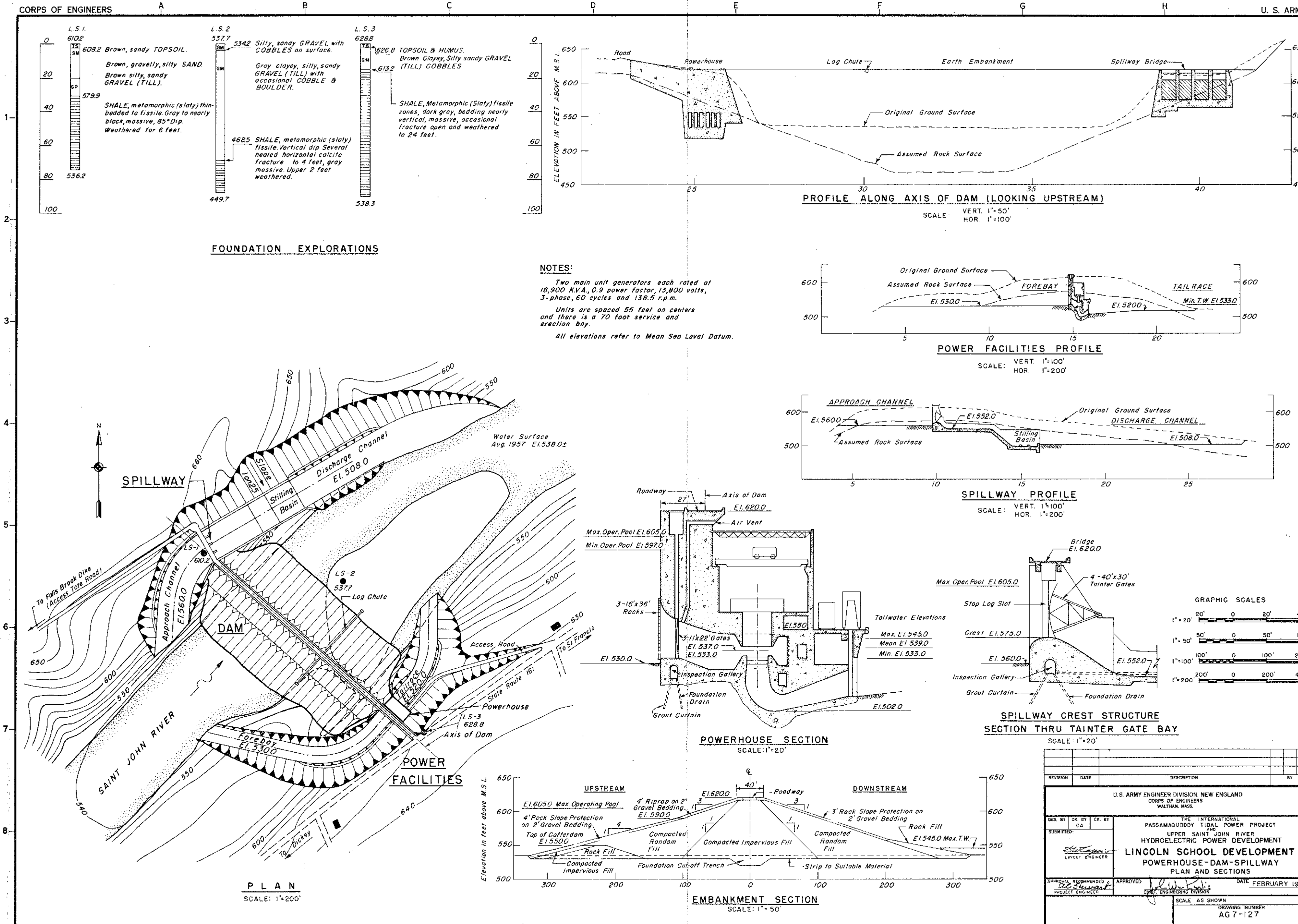
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT
POWERHOUSE
PLAN AND SECTIONS

DES. BY | DR. BY M.S. | CK. BY
SUBMITTED: LAYOUT ENGINEER
APPROVAL RECOMMENDED: PROJECT ENGINEER
APPROVED: CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE: AS SHOWN
DRAWING NUMBER AG7-126

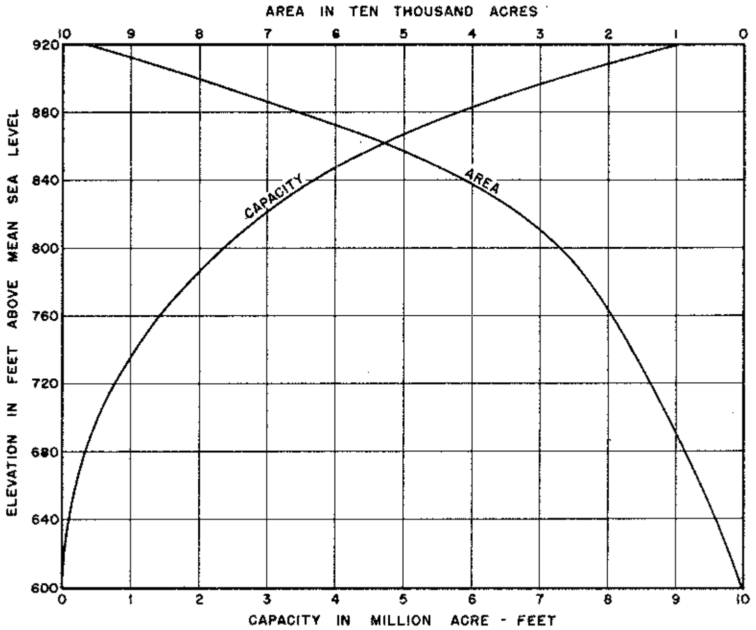
PLATE NO. 8



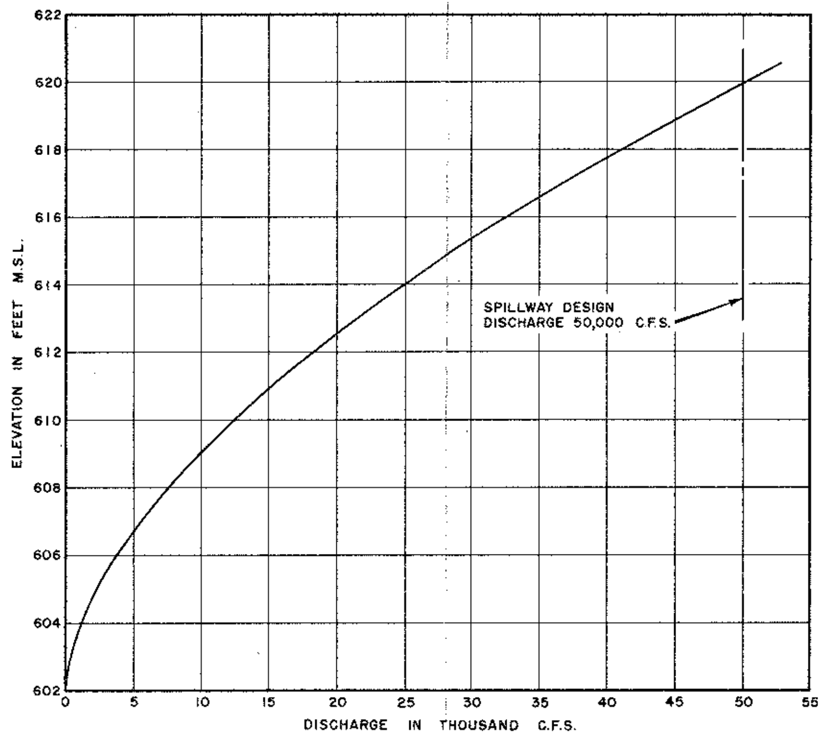
CORPS OF ENGINEERS
U. S. ARMY
L.S.1 610.2
608.2 Brown, sandy TOPSOIL.
Brown, gravelly, silty SAND.
Brown silty, sandy GRAVEL (TILL).
579.9
SHALE, metamorphic (slaty) thin-bedded to fissile. Gray to nearly black, massive, 85° Dip. Weathered for 6 feet.
536.2
L.S.2 537.7
534.2 Silty, sandy GRAVEL with COBBLES on surface.
Gray clayey, silty, sandy GRAVEL (TILL) with occasional COBBLE & BOULDER.
468.5 SHALE, metamorphic (slaty) fissile. Vertical dip. Several healed horizontal calcite fracture to 4 feet, gray massive. Upper 2 feet weathered.
449.7
L.S.3 628.8
626.8 TOPSOIL & HUMUS.
Brown Clayey, Silty sandy GRAVEL (TILL) COBBLES
613.2
SHALE, Metamorphic (Slaty) fissile zones, dark gray, bedding nearly vertical, massive, occasional fracture open and weathered to 24 feet.
538.3
FOUNDATION EXPLORATIONS
Road
Powerhouse
Log Chute
Earth Embankment
Spillway Bridge
Original Ground Surface
Assumed Rock Surface
ELEVATION IN FEET ABOVE M.S.L.
PROFILE ALONG AXIS OF DAM (LOOKING UPSTREAM)
SCALE: VERT. 1"=50' HOR. 1"=100'
NOTES:
Two main unit generators each rated at 18,900 K.V.A., 0.9 power factor, 13,800 volts, 3-phase, 60 cycles and 138.5 r.p.m.
Units are spaced 55 feet on centers and there is a 70 foot service and erection bay.
All elevations refer to Mean Sea Level Datum.
Original Ground Surface
Assumed Rock Surface
FOREBAY
TAILRACE
El. 530.0
El. 520.0
Min. T.W. El. 533.0
POWER FACILITIES PROFILE
SCALE: VERT. 1"=100' HOR. 1"=200'
APPROACH CHANNEL
El. 560.0
El. 552.0
Original Ground Surface
DISCHARGE CHANNEL
Stilling Basin
El. 508.0
Assumed Rock Surface
SPILLWAY PROFILE
SCALE: VERT. 1"=100' HOR. 1"=200'
SPILLWAY
Discharge Channel El. 508.0
Stilling Basin
Slope
Water Surface Aug. 1957 El. 538.0±
To Falls Brook Dike (Access Tote Road)
LS-1 610.2
Approach Channel El. 560.0
DAM
LS-2 537.7
Log Chute
Access Road
To St. Francis
State Route 161
Tailrace El. 520.0
Powerhouse
LS-3 628.8
Axis of Dam
SAINT JOHN RIVER
Forebay El. 530.0
POWER FACILITIES
To Dickey
PLAN
SCALE: 1"=200'
Roadway
27'
Axis of Dam
El. 620.0
Air Vent
Max. Oper. Pool El. 605.0
Min. Oper. Pool El. 597.0
3-16'x36' Racks
El. 550
3-11'x22' Gates
El. 537.0
El. 533.0
El. 530.0
Inspection Gallery
Foundation Drain
Grout Curtain
Tailwater Elevations
Max. El. 545.0
Mean El. 539.0
Min. El. 533.0
El. 502.0
POWERHOUSE SECTION
SCALE: 1"=20'
Bridge El. 620.0
Max. Oper. Pool El. 605.0
4-40'x30' Tainter Gates
Stop Log Slot
Crest El. 575.0
El. 560.0
El. 552.0
Inspection Gallery
Grout Curtain
Foundation Drain
SPILLWAY CREST STRUCTURE
SECTION THRU TAINTER GATE BAY
SCALE: 1"=20'
GRAPHIC SCALES
UPSTREAM
DOWNSTREAM
El. 605.0 Max. Operating Pool
4' Riprap on 2' Gravel Bedding El. 590.0
El. 620.0
40'
Roadway
4' Rock Slope Protection on 2' Gravel Bedding
Top of Cofferdam El. 550.0
Rock Fill
Compacted Impervious Fill
Compacted Random Fill
Compacted Impervious Fill
Foundation Cut-off Trench
Strip to Suitable Material
Compacted Random Fill
3' Rock Slope Protection on 2' Gravel Bedding
Rock Fill
El. 545.0 Max. T.W.
Elevation in feet above M.S.L.
EMBANKMENT SECTION
SCALE: 1"=50'
REVISION DATE DESCRIPTION BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT
LINCOLN SCHOOL DEVELOPMENT
POWERHOUSE-DAM-SPILLWAY
PLAN AND SECTIONS
LAYOUT ENGINEER
PROJECT ENGINEER
CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE AS SHOWN
DRAWING NUMBER AG7-127

PLATE NO. 9

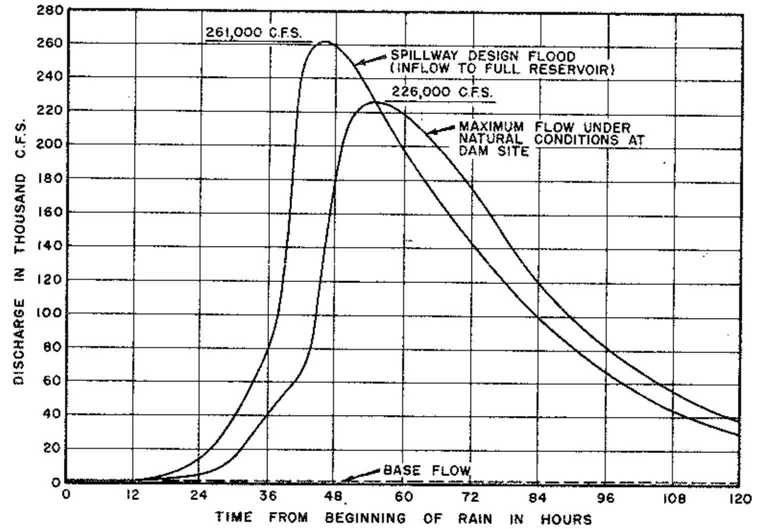
CORPS OF ENGINEERS — U. S. ARMY



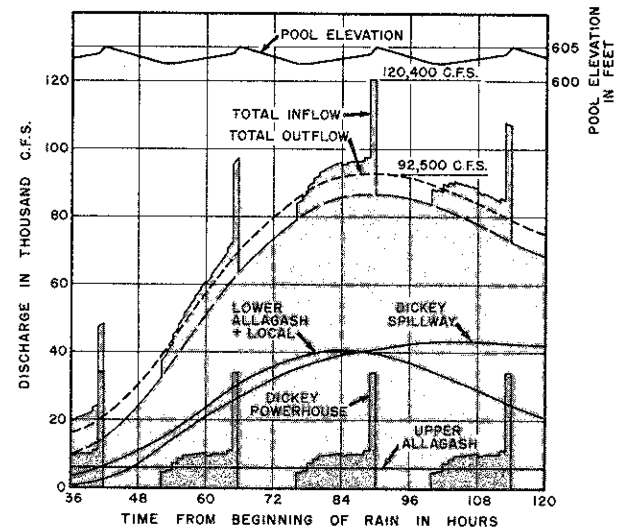
DICKEY RESERVOIR



DICKEY SPILLWAY

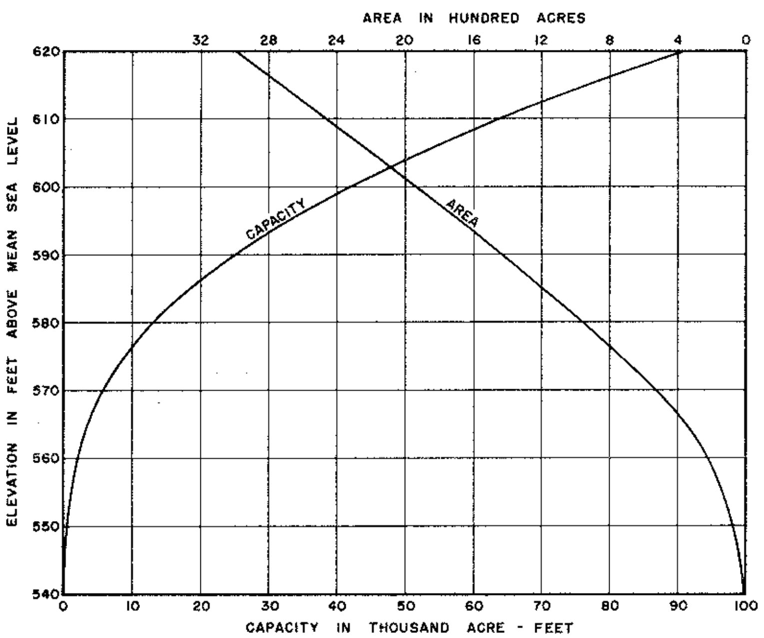


DICKEY RESERVOIR



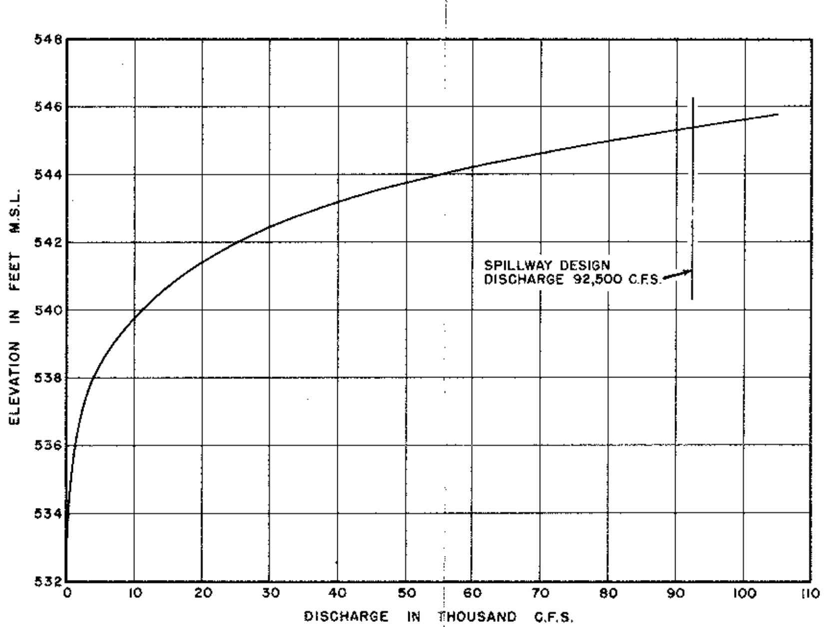
LINCOLN SCHOOL POOL

SPILLWAY DESIGN FLOOD HYDROGRAPHS



LINCOLN SCHOOL POOL

AREA AND CAPACITY CURVES



LINCOLN SCHOOL DAM

TAILWATER RATING CURVES

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY E.A.W. — DR. BY M.S. — CK. BY

SUBMITTED: L. Reid, HYDRAULIC ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY AND LINCOLN SCHOOL
HYDROLOGY

APPROVAL RECOMMENDED: PROJECT ENGINEER

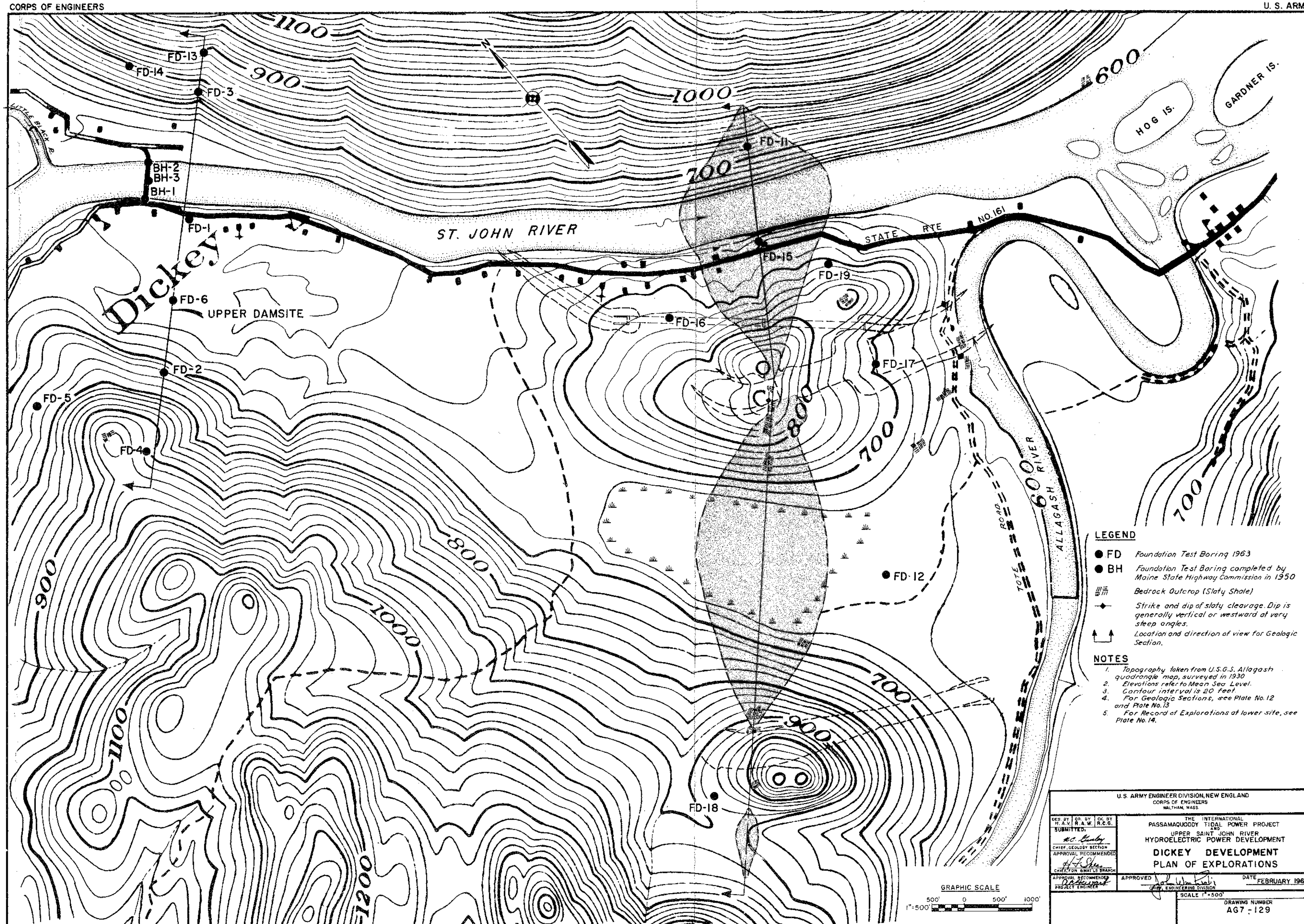
APPROVED: CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

SCALE: AS SHOWN

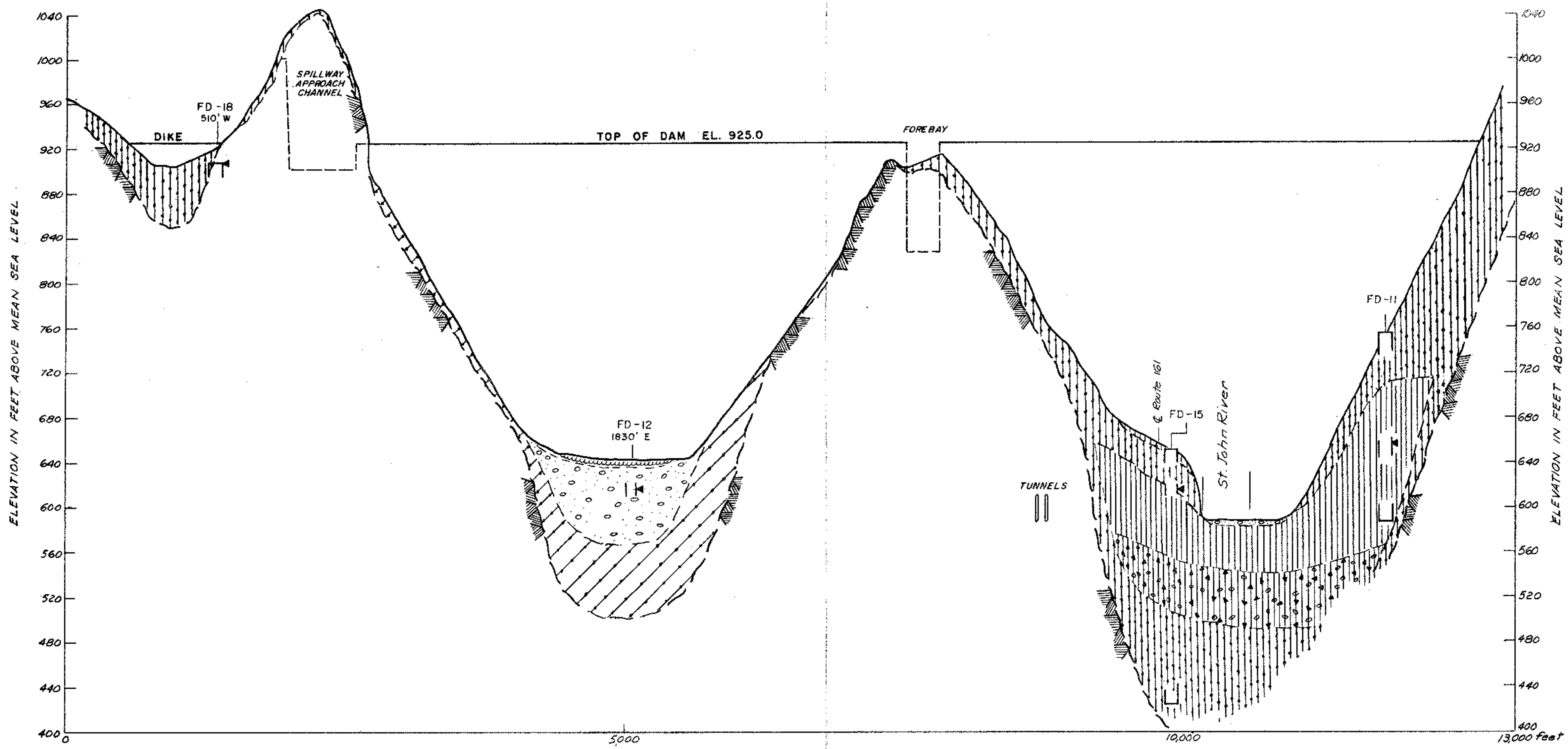
DRAWING NUMBER AG7-128

PLATE NO. 10



1100
900
1000
600
700
800
1200
FD-13
FD-14
FD-3
FD-11
FD-1
FD-15
FD-19
FD-6
FD-16
FD-2
FD-17
FD-5
FD-4
FD 12
FD-18
BH-2
BH-3
BH-1
LITTLE BLACK R.
HOG IS.
GARDNER IS.
ST. JOHN RIVER
STATE RTE NO. 161
Dickey
UPPER DAMSITE
ALLAGASH RIVER
TOTE ROAD
N
LEGEND
FD Foundation Test Boring 1963
BH Foundation Test Boring completed by Maine State Highway Commission in 1950
Bedrock Outcrop (Slaty Shale)
Strike and dip of slaty cleavage. Dip is generally vertical or westward at very steep angles.
Location and direction of view for Geologic Section.
NOTES
1. Topography taken from U.S.G.S. Allagash quadrangle map, surveyed in 1930
2. Elevations refer to Mean Sea Level.
3. Contour interval is 20 feet
4. For Geologic Sections, see Plate No. 12 and Plate No. 13
5. For Record of Explorations at lower site, see Plate No. 14.
GRAPHIC SCALE
500' 0 500' 1000'
1"=500'
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY H.A.V.
DR. BY R.A.W.
CK. BY R.C.G.
SUBMITTED:
CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED
CHIEF, FDN & MAT'LS BRANCH
APPROVAL RECOMMENDED
PROJECT ENGINEER
THE INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT
DICKEY DEVELOPMENT
PLAN OF EXPLORATIONS
APPROVED
CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE 1"=500'
DRAWING NUMBER
AG7-129

PLATE NO. 11

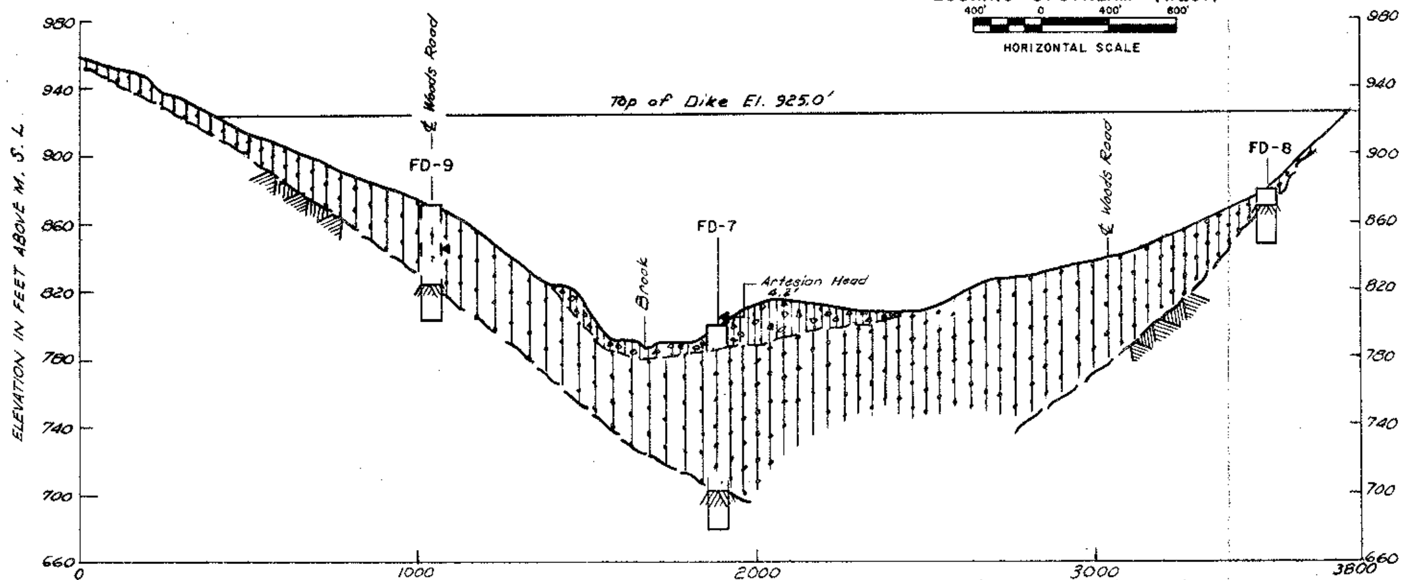


DICKEY DAM

LOOKING UPSTREAM (WEST)

400' 0 400' 800'

HORIZONTAL SCALE



FALLS BROOK DIKE (LOOKING SOUTH)

200' 0 200' 400'

HORIZONTAL SCALE

LEGEND

- Gravelly, silty SAND (TILL); Gravelly, silty, clayey SAND (TILL); Silty, sandy Gravel (TILL)
- Gravelly, sandy SILT (TILL); Gravelly, silty, sandy CLAY (TILL); Silty, sandy, gravelly CLAY (TILL); Sandy CLAY (TILL)
- Silty SANDS and GRAVELS in part TILL; Silty gravelly SAND in part TILL
- Silty SANDS and GRAVELS; Silty gravelly SANDS
- Silty SAND and SILT; Silty SAND, sandy SILT, clayey SILT
- SILT and CLAY
- PEAT
- Assumed Rock Surface

Bedrock is dark gray, hard slaty SHALE generally slightly calcareous. Strike generally N 40° to 50° East. Dip Vertical to 70° Westward.

NOTES

1. All sections taken along surveyed profiled lines. Locations of sections for Lower and Upper Damsites are shown on Plate No. 11. General location of Falls Brook Dike is shown on Plate No. 5.
2. Elevations refer to Mean Sea Level.
3. FD Foundation Test Boring
4. Symbol denotes level of Subsurface water boring during drilling.
5. Denotes bottom of boring.
6. For Record of Explorations see Plate No. 14

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DES. BY H.A.V. | DR. BY L.H.I. | CK. BY R.G.G.

SUBMITTED H.C. Gurley, CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED: CHIEF, FDN. & MAT'LS BRANCH

APPROVAL RECOMMENDED: PROJECT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT

DICKEY DAM - FALLS BROOK DIKE

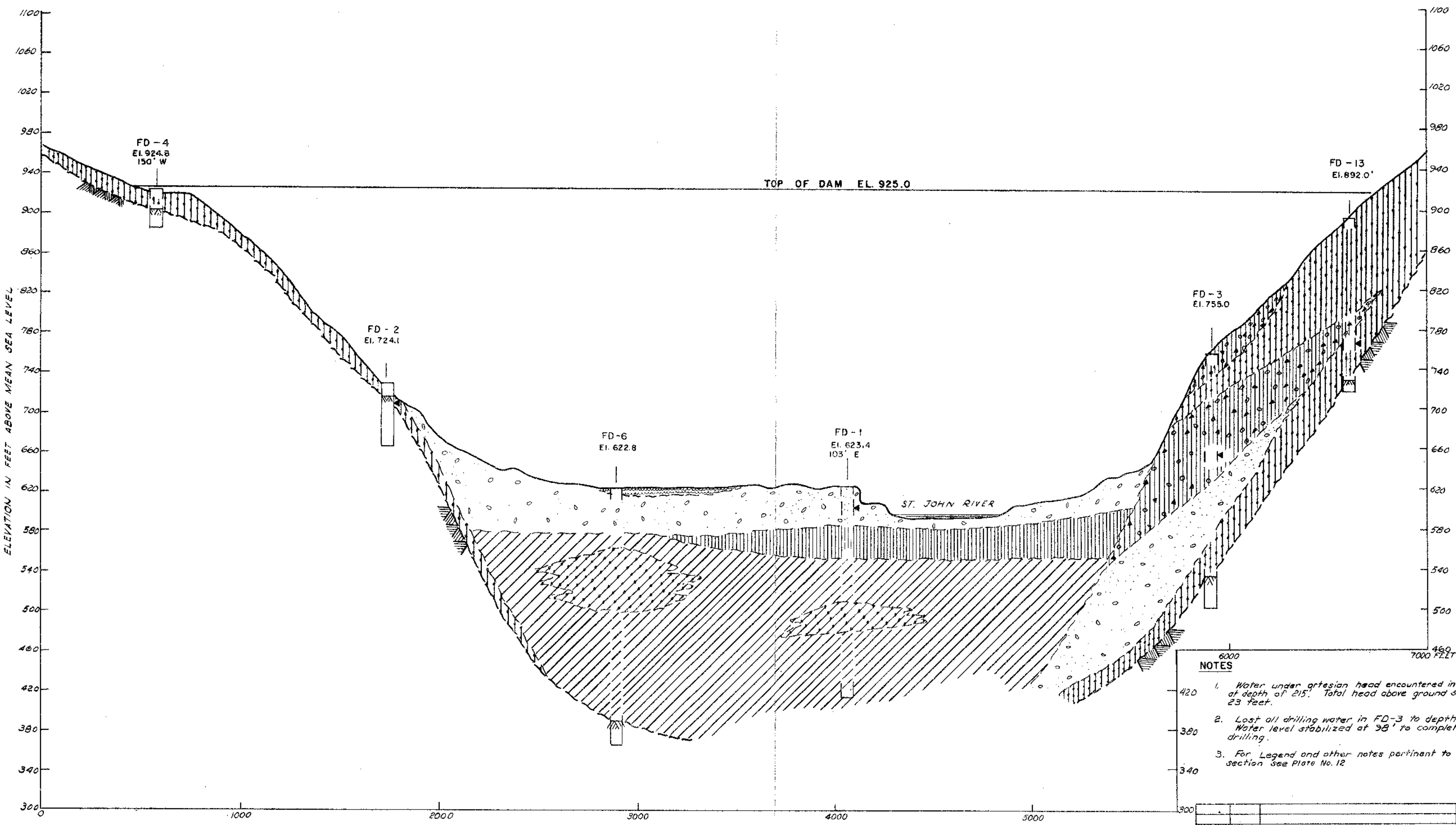
GEOLOGIC SECTIONS

APPROVED: CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

SCALE AS SHOWN

DRAWING NUMBER AG7-130



DAM - UPPER SITE

LOOKING UPSTREAM (WEST)

200' 0 200' 400'

HORIZONTAL SCALE

NOTES

1. Water under artesian head encountered in FD-6 at depth of 215'. Total head above ground surface 23 feet.
2. Lost all drilling water in FD-3 to depth of 150'. Water level stabilized at 98' to completion of drilling.
3. For Legend and other notes pertinent to the section see Plate No. 12

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DES. BY H.A.V. | DR. BY L.H.I. | CK. BY W.C.G.

SUBMITTED W. C. Gurley, CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED H. J. Shea, CHIEF, FDN. & MAT'LS BRANCH

APPROVAL RECOMMENDED A. C. Stewart, PROJECT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT
UPPER DAMSITE
GEOLOGIC SECTION

APPROVED John Wm. Leslie, CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

SCALE AS SHOWN

DRAWING NUMBER AG7-131

PLATE NO. 13

CORPS OF ENGINEERS

U. S. ARMY

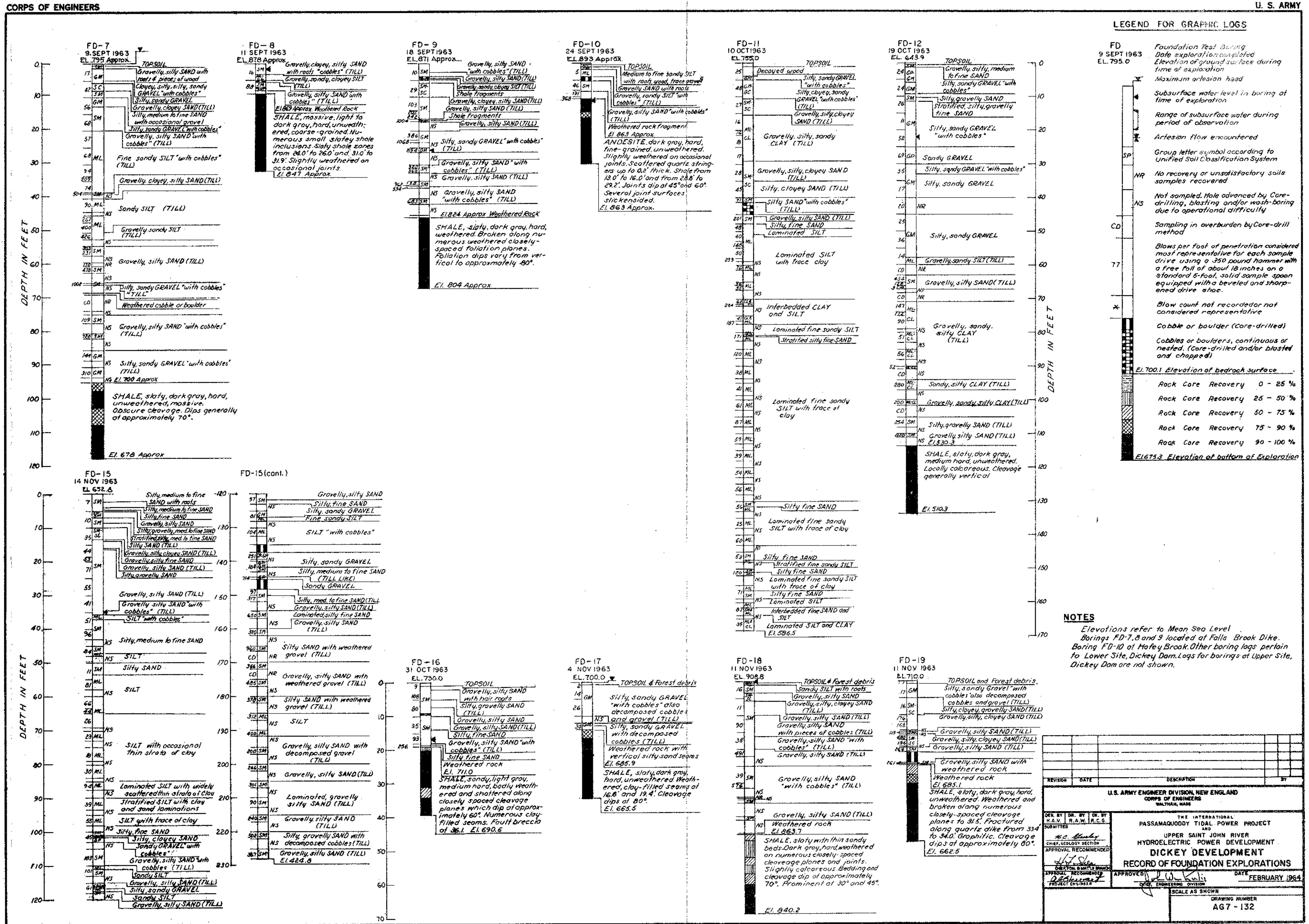


PLATE NO. 14

SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT

AND

UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

APPENDIX I

ARMY-INTERIOR ADVISORY BOARD

SUPPLEMENTARY ENGINEERING REPORT

CORPS OF ENGINEERS

APRIL 1964

APPENDIX I

ARMY-INTERIOR ADVISORY BOARD ON

PASSAMAQUODDY AND UPPER SAINT JOHN RIVER

Name	Position and Agency
W. E. Johnson, Chairman	Chief, Engineering Division Directorate of Civil Works Office of the Chief of Engineers Department of the Army Washington, D. C.
H. C. C. Weinkauff	Chief, Planning Division Directorate of Civil Works Office of the Chief of Engineers Department of the Army Washington, D. C.
F. L. Thrall	Engineer, Multiple Use Coordination Branch Directorate of Civil Works Office of the Chief of Engineers Department of the Army Washington, D. C.
J. W. Leslie	Chief, Engineering Division U. S. Army Engineer Division, New England Waltham, Massachusetts
M. D. Dubrow	Assistant and Chief Engineering Research Advisor Department of the Interior Washington, D. C.
N. B. Bennett	Assistant Commissioner Bureau of Reclamation Department of the Interior Washington, D. C.
J. E. Guidry	Engineer, Office of Assistant Secretary for Water and Power Department of the Interior Washington, D. C.

ARMY-INTERIOR ADVISORY BOARD ON

PASSAMAQUODDY AND UPPER SAINT JOHN RIVER

(continued)

Name	Position and Agency
B. P. Bellport	Chief Engineer Bureau of Reclamation Department of the Interior Denver, Colorado
F. S. Brown	Chief Engineer Federal Power Commission Washington, D. C.
D. A. Portner	Deputy Assistant Administrator for Industrial Analysis Business and Defense Services Administration Department of Commerce Washington, D. C.
T. W. Barry	Resources and Civil Works Division Bureau of the Budget Executive Office Washington, D. C.
M. Kaplan	Council of Economic Advisers Executive Office Washington, D. C.
R. Barlow	Office of Science and Technology Executive Office Washington,D. C.
A. Giambusso	Atomic Energy Commission Washington, D. C.
J. W. Roche, Secretary	Engineer, Policy and Legislative Branch Directorate of Civil Works Office of the Chief of Engineers Department of the Army Washington, D. C.

SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT

AND

UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

APPENDIX II

ESTIMATES OF COST

SUPPLEMENTARY ENGINEERING REPORT

CORPS OF ENGINEERS

APRIL 1964

SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

APPENDIX II

ESTIMATES OF COST

CONTENTS

APPENDIX II

Table 1

WAGE RATES

Listed below are the wage rates for key positions that have been used for the cost estimates in this report.

Classification	Rate Per Hour
Crane & shovel operators	$ 5.10
Oilers	3.65
Carpenters	2.75
Cement masons	4.00
Iron workers, structural	4.45
" " , reinforcing	4.15
Truck drivers, heavy equip.	2.25
Laborers	2.00
Dipper dredge operator	3.93
" " deck hand	2.74

Table 2

CONSTRUCTION EQUIPMENT RATES

The ownership rates of typical pieces of construction equipment used as a basis for the cost estimates are listed below.

Land-based Equipment	Ownership Rates per 8-Hr./Day
Air compressor, diesel, 900 cfm	$ 32
Wagon drill, 4"	18
Crane, 30-ton diesel	55
Shovel, 4 c.y. diesel	172
Bulldozer, 200 HP	72
Truck, 35 c.y.	120
" 15 c.y.	60

Marine Equipment	Ownership Rates per 24-Hr./Day
Derrick lighter - 25-ton, $2\frac{1}{2}$ c.y.	$ 300
Dipper dredge, 15 c.y.	2,500
Hydraulic dredge, 28-inch	3,000
Dump scow, 1,500 c.y.	250
Tow boat, 450 HP	250
" " 900 HP	400
Work or fuel boat, 150 HP	80

APPENDIX II

Table 3

TIDAL POWER PROJECT - 300 mw

Item	Quantity	Unit	Unit Price	Amount
1. POWERPLANT - No. 1- 300 mw				
a. Cofferdams			L.S.	$ 7,250,000
b. Excavation				
(1) Earth				
(a) By hydraulic dredge	16,000,000	cy	.60	9,600,000
(b) In dry	980,000	cy	1.00	980,000
(2) Rock	5,840,000	cy	1.90	11,096,000
Excavation				$ 21,676,000
c. Powerhouse			L.S.	30,447,000
d. Intake gates			L.S.	1,679,000
e. Draft tube gates			L.S.	1,574,000
f. Turbines and generators			L.S.	48,949,000
g. Accessory elect. equip .			L.S.	5,271,000
h. Misc. powerplant equip.			L.S.	1,593,000
i. Power transformers			L.S.	750,000
TOTAL POWER PLANT				$ 119,189,000
2. SWITCHYARD				$ 1,780,000
3. LETITE PASSAGE FILLING GATES (Table 7)				$ 27,472,000
4. WESTERN PASSAGE FILLING GATES (Table 8)				$ 35,162,000
5. HEAD HARBOUR EMPTYING GATES (Table 9)				$ 57,627,000
6. LOCKS (Tables 10-13)				$ 18,917,000
7. DAMS				
a. Cost for 500 mw - P.P. (Table 14)			L.S.	$ 63,664,000
b. Extra cost to borrow	10,660,000		1.28	13,645,000
TOTAL DAMS				$ 77,309,000

Table 3 - Continued

	Item	Quantity	Unit	Unit Price	Amount
8.	LUBEC CHANNEL (Table 15)				$ 634,000
9.	FISHWAYS				
	a. Powerplant (Table 16 mod.)			L.S.	616,000
	b. Head Harbour emptying gates (Table 16)			L.S.	272,000
	TOTAL FISHWAYS				$ 888,000
10.	SERVICE FACILITIES (Table 17 mod.)				$ 1,670,000
11.	RELOCATIONS				
	a. Relocations in United States				
	(1) Roads and bridges				
	(a) Highways				$ 54,000
	(b) Railroad				212,000
	(c) Highway and railroad bridge (Table 18 mod.)				3,153,000
	Roads and bridges				$ 3,419,000
	(2) Waterlines				64,000
	(3) Tel. and tel. lines				30,000
	(4) Electric lines				55,000
	(5) Cemeteries				2,000
	(6) U. S. Coast Guard				250,000
	(7) International boundary monuments				10,000
	Relocations in United States				$ 3,830,000
	b. Relocations in Canada				99,000
	TOTAL RELOCATIONS				$ 3,929,000
12.	LANDS AND DAMAGES (Table 19)				1,870,000
	SUB-TOTAL				$ 346,447,000
	Contingencies				49,520,000
	SUB-TOTAL				$ 395,967,000
	Engineering, design supervision & administration				43,478,000
	PROJECT FIRST COST (300 mw)				$ 439,445,000

APPENDIX II

Table 4

TIDAL POWER PROJECT - 500 mw

Item	Quantity	Unit	Unit price	Amount
1. POWERPLANT - No. 1 - 500 mw				
a. Cofferdams			L.S.	$ 9,700,000
b. Excavation				
(1) Earth				
(a) By hydraulic dredge	23,000,000	c.y.	.60	13,800,000
(b) In dry	2,000,000	c.y.	1.00	2,000,000
(2) Rock	15,000,000	c.y.	1.90	28,500,000
Excavation				$44,300,000
c. Powerhouse				
(1) Substructure				
(a) Foundation preparation	74,000	s.y.	4.00	$ 296,000
(b) Concrete	926,000	c.y.	49.00	45,374,000
(c) Water stops & seals			L.S.	305,000
(d) Misc. blockouts			L.S.	234,000
(2) Superstructure				
(a) Concrete	9,200	c.y.	90.00	828,000
(b) Steel and ironwork				
1) Steel for roof			L.S.	670,000
2) Crane rails	1,483,000	lbs.	.20	297,000
3) Misc. items			L.S.	396,000
(c) Roof			L.S.	350,000
(d) Architectural features			L.S.	874,000
(e) Plumbing			L.S.	229,000
(f) Heating & ventilating			L.S.	333,000
(g) Lighting			L.S.	556,000
(h) Misc.			L.S.	3,000
Powerhouse				$50,745,000

Table 4 - Continued

Item	Quantity	Unit	Unit price	Amount
d. Intake gates				
(1) Gates & guides			L.S.	$ 1,026,000
(2) Trash racks & stop logs			L.S.	1,616,000
(3) Grating covers & frames			L.S.	90,000
(4) Painting			L.S.	67,000
	Intake gates			$ 2,799,000
e. Draft tube gates				
(1) Gates & guides			L.S.	$ 2,473,000
(2) Grating covers & frames			L.S.	76,000
(3) Painting			L.S.	75,000
	Draft tube gates			$ 2,624,000
f. Turbines and generators				
(1) Turbines, governors, speed increasers & generators	50	ea.	1,608,200	$80,410,000
(2) Lube system			L.S.	250,000
(3) Cooling system			L.S.	670,000
(4) Fire protection system			L.S.	252,000
	Turbines and generators			$81,582,000
g. Accessory electrical equipment			L.S.	$ 8,785,000
h. Misc. powerplant equipment			L.S.	$ 2,656,000

Table 4 - Continued

	Item	Quantity	Unit	Unit price	Amount
	i. Power transformers			L.S.	$ 1,300,000
		TOTAL POWER PLANT			$204,491,000
2.	SWITCHYARD				
	a. Circuit breakers			L.S.	557,000
	b. Disconnect switches			L.S.	235,000
	c. Grading, structures, bus, etc.			L.S.	1,578,000
		TOTAL SWITCHYARD			$ 2,370,000
3.	LETITE PASSAGE FILLING GATES (Table 7)				$ 27,472,000
4.	WESTERN PASSAGE FILLING GATES (Table 8)				35,162,000
5.	HEAD HARBOUR PASSAGE EMPTYING GATES (Table 9)				57,627,000
6.	HEAD HARBOUR PASSAGE LOCK (Table 10)				7,472,000
7.	WESTERN PASSAGE LOCK (Table 11)				6,943,000
8.	LITTLE LETITE PASSAGE LOCK (Table 12)				1,756,000
9.	QUODDY ROADS LOCK (Table 13)				2,746,000
10.	DAMS (Table 14)				63,664,000
11.	LUBEC CHANNEL (Table 15)				634,000
12.	FISHWAYS (Table 16)				1,298,000
13.	SERVICE FACILITIES (Table 17)				1,870,000

Table 4 - Continued

	Item	Quantity	Unit	Unit Price	Amount
14.	RELOCATIONS (Table 18)				$ 4,931,000
15.	LANDS AND DAMAGES (Table 19)				1,870,000
	SUB-TOTAL				$ 420,306,000
	Contingencies				58,967,000
	SUB-TOTAL				$ 479,273,000
	Engineering, design, supervision & administration				50,581,000
	PROJECT FIRST COST (500 mw)				$ 529,854,000

APPENDIX II

Table 5

TIDAL POWER PROJECT - 700 mw

Item	Quantity	Unit	Unit Price	Amount
1. POWERPLANT				
a. Powerplant No. 1 - 500 mw (Table 4)				$204,491,000
b. Powerplant No. 2 - 200 mw				
(1) Cofferdams			L.S.	9,700,000
(2) Excavation				
(a) Earth				
1) By hydraulic dredge	8,800,000	cy	.60	5,280,000
2) In dry	1,000,000	cy	1.00	1,000,000
(b) Rock				
1) In dry	9,800,000	cy	1.90	18,620,000
2) Underwater	200,000	cy	15.00	3,000,000
Excavation				$ 27,900,000
(3) Powerhouse and equipment				60,196,000
Powerplant No. 2 - 200 mw				97,796,000
TOTAL POWERPLANTS - 700 mw				$302,287,000
2. SWITCHYARD				$ 3,160,000
3. FILLING GATES (Tables 7-8)				$ 62,634,000
4. EMPTYING GATES (Table 9)				$ 57,627,000
5. LOCKS (Tables 10-13)				$ 18,917,000
6. DAMS				
a. For 500 mw project (Table 14)				$ 63,664,000
b. Bar Harbor Dam				790,000
TOTAL DAMS				$ 64,454,000

Table 5 - Continued

Item	Quantity	Unit	Unit Price	Amount
7. LUBEC CHANNEL (Table 15)				$ 634,000
8. FISHWAYS				
a. For 500 mw project (Table 16)				$1,298,000
b. For PH #2 - 200 mw				450,000
TOTAL FISHWAYS				$1,748,000
9. SERVICE FACILITIES				
a. For 500 mw project (Table 17)				1,870,000
b. For 200 mw addition				200,000
TOTAL SERVICE FACILITIES				$2,070,000
10. RELOCATIONS				
a. For 500 mw project (Table 18)				4,931,000
b. For 200 mw addition				
(1) Highway and railroad bridge				2,250,000
(2) Highways				150,000
(3) Waterlines				100,000
TOTAL RELOCATIONS				$7,431,000
11. LANDS AND DAMAGES				
a. For 500 mw project (Table 19)				$1,879,000
b. For 200 mw addition				90,000
TOTAL LANDS & DAMAGES				$1,960,000
SUB-TOTAL				$522,922,000
Contingencies				72,728,000
SUB-TOTAL				$595,650,000
Engineering, design, supervision & administration				61,221,000
PROJECT FIRST COST (700 mw)				$656,871,000

APPENDIX II

Table 6

TIDAL POWER PROJECT - 1000 mw

Item	Quantity	Unit	Unit Price	Amount
1. POWERPLANT				
a. Powerplant No. 1 - 500 mw (Table 4)				$204,491,000
b. Powerplant No. 2 - 500 mw				
(1) Cofferdams			L.S.	$ 11,200,000
(2) Excavation				
(a) Earth				
1) By hydraulic dredge	20,500,000	cy	.60	$ 12,300,000
2) In dry	2,000,000	cy	1.00	2,000,000
(b) Rock				
1) In dry	22,200,000	cy	1.90	42,180,000
2) Underwater	300,000	cy	15.00	4,500,000
Excavation				$ 60,980,000
(3) Powerhouse and equipment				$150,491,000
Powerplant No. 2 - 500 mw				$222,671,000
TOTAL POWERPLANTS-1000 mw				$427,162,000
2. SWITCHYARD				3,950,000
3. FILLING GATES (Tables 7 & 8)				62,634,000
4. EMPTYING GATES (Table 9)				57,627,000
5. LOCKS (Tables 10-13)				18,917,000
6. DAMS				
a. For 500 - mw project (Table 14)				63,664,000
b. Bar Harbor dam				790,000
TOTAL DAMS				$ 64,454,000
7. LUBEC CHANNEL (Table 15)				$ 634,000

Table 6 - Continued

Item	Quantity	Unit	Unit Price	Amount
8. FISHWAYS				
a. For 500 - mw project (Table 16)				$ 1,298,000
b. For 500 mw - addition				1,026,000
				$ 2,324,000
9. SERVICE FACILITIES				
a. For 500 - mw project (Table 17)				1,870,000
b. For 500 - mw addition				600,000
TOTAL SERVICE FACILITIES				$ 2,470,000
10. RELOCATIONS				
a. For 500 - mw project (Table 18)				$ 4,931,000
b. For 500 - mw addition				4,700,000
TOTAL RELOCATIONS				$ 9,631,000
11. LANDS AND DAMAGES				
a. For 500 - mw project (Table 19)				$ 1,870,000
b. For 500 - mw addition				160,000
TOTAL LANDS AND DAMAGES				$ 2,030,000
SUB-TOTAL				$651,833,000
Contingencies				89,616,000
SUB-TOTAL				$741,449,000
Engineering, design, supervision & administration				74,482,000
PROJECT FIRST COST (1000-mw)				$ 815,931,000

APPENDIX II

Table 7

TIDAL POWER PROJECT

LETITE PASSAGE FILLING GATES

	Item	Quantity	Unit	Unit Price	Amount
a.	Cofferdams			L.S.	$ 6,526,000
b.	Excavation				
	(1) Earth, in dry	419,000	cy	1.00	419,000
	(2) Rock, in dry	1,695,000	cy	2.00	3,390,000
	(3) Rock, under water	83,500	cy	15.00	1,253,000
	(4) Backfill	10,900	cy	.20	2,000
		Excavation			$ 5,064,000
c.	Concrete				
	(1) Foundation preparation				$ 128,000
	(2) Foundation mat	16,800	cy	25.00	420,000
	(3) Gate structure	128,000	cy	59.00	7,552,000
		Concrete			$ 8,100,000
d.	Gates and Machinery				
	(1) Service gates & guides			L.S.	$ 3,807,000
	(2) Machinery			L.S.	772,000
	(3) Emergency gates & guides			L.S.	2,291,000
	(4) Unwatering bulkheads			L.S.	155,000
	(5) Gantry crane & rails			L.S.	257,000
	(6) Electrical items			L.S.	226,000
		Gates and machinery			$ 7,508,000
e.	Operations building			L.S.	$ 56,000
f.	Misc. items			L.S.	218,000
	TOTAL LETITE PASSAGE FILLING GATES				$ 27,472,000

APPENDIX II

Table 8

TIDAL POWER PROJECT

WESTERN PASSAGE FILLING GATES

	Item	Quantity	Unit	Unit Price	Amount
a.	Cofferdams			L.S.	$ 3,719,000
b.	Excavation				
	(1) Earth, in dry	406,250	cy	1.00	$ 406,000
	(2) Rock, in dry	4,325,000	cy	2.00	8,650,000
	(3) Rock, under water	228,000	cy	15.00	3,420,000
		Excavation			$ 12,476,000
c.	Concrete				
	(1) Foundation preparation			L.S.	$ 180,000
	(2) Gate structure	158,000	cy	58.00	9,170,000
		Concrete			$ 9,350,000
d.	Gates and machinery				
	(1) Service gates & guides			L.S.	$ 4,750,000
	(2) Machinery			L.S.	965,000
	(3) Emergency gates & guides			L.S.	2,852,000
	(4) Unwatering bulkheads			L.S.	174,000
	(5) Gantry crane & rails			L.S.	271,000
	(6) Electrical items			L.S.	280,000
		Gates and machinery			$ 9,292,000
e.	Operations building				$ 55,000
f.	Misc. items				270,000
	TOTAL WESTERN PASSAGE FILLING GATES				$ 35,162,000

APPENDIX II

Table 9

TIDAL POWER PROJECT

HEAD HARBOUR PASSAGE EMPTYING GATES

	Item	Quantity	Unit	Unit Price	Amount
a.	Cofferdams				$18,923,000
b.	Excavation				
	(1) Earth, by dredge	410,000	cy	1.10	$ 451,000
	(2) Rock, in dry	2,172,000	cy	2.00	4,344,000
	(3) Rock, underwater	152,000	cy	15.00	2,280,000
	(4) Backfill	82,400	cy	.20	16,000
		Excavation			$ 7,091,000
c.	Concrete				
	(1) Foundation preparation			L.S.	$ 237,000
	(2) Foundation mat	90,735	cy	25.00	2,268,000
	(3) Gate structure	252,300	cy	58.00	14,633,000
		Concrete			$17,138,000
d.	Gates and machinery				
	(1) Service gates & guides			L.S.	7,203,000
	(2) Machinery			L.S.	1,351,000
	(3) Emergency gates & guides			L.S.	4,548,000
	(4) Unwatering bulkheads			L.S.	220,000
	(5) Gantry crane & rails			L.S.	301,000
	(6) Electrical items			L.S.	388,000
		Gates and machinery			$14,011,000
e.	Operations building			L.S.	57,000
f.	Misc. items			L.S.	407,000
	TOTAL HEAD HARBOUR PASSAGE EMPTYING GATES				$57,627,000

APPENDIX II

Table 10

TIDAL POWER PROJECT

HEAD HARBOUR PASSAGE LOCK

Item	Quantity	Unit	Unit Price	Amount
a. Cofferdams			L.S.	$1,467,000
b. Excavation				
(1) Earth, in dry	51,500	cy	1.50	$ 77,000
(2) Rock				
(a) In dry	917,450	cy	2.00	$1,835,000
(b) Underwater	48,000	cy	15.00	720,000
(c) Backfill	60,500	cy	.20	12,000
(d) Fine rock grading	40,000	sy	2.25	90,000
Excavation				$2,734,000
c. Concrete				
(1) Foundation preparation			L.S.	28,000
(2) Lock structure	53,500	cy	42.00	2,247,000
Concrete				$ 2,275,000
d. Gates and machinery				
(1) Gates			L.S.	$ 342,000
(2) Machinery			L.S.	109,000
(3) Unwatering bulkheads			L.S.	267,000
(4) Service bridge			L.S.	100,000
(5) Electrical items			L.S.	138,000
Gates and machinery				$ 956,000
e. Operations building			L.S.	16,000
f. Misc. items			L.S.	24,000
TOTAL HEAD HARBOUR PASSAGE LOCK				$ 7,472,000

APPENDIX II

Table 11

TIDAL POWER PROJECT

WESTERN PASSAGE LOCK

	Item	Quantity	Unit	Unit Price	Amount
a.	Cofferdams			L.S.	$ 1,934,000
b.	Excavation				
	(1) Earth, in dry	303,840	c.y.	1.00	$ 304,000
	(2) Rock				
	(a) In dry	578,070	c.y.	2.00	1,156,000
	(b) Underwater	4,230	c.y.	25.00	106,000
	(c) Backfill	52,800	c.y.	.20	11,000
	(d) Fine rock grading	52,000	s.y.	2.25	117,000
	Excavation				$ 1,694,000
c.	Concrete				
	(1) Foundation preparation			L.S.	$ 41,000
	(2) Lock structure	57,500	c.y.	40.00	2,300,000
	Concrete				$ 2,341,000
d.	Gates and machinery				
	(1) Gates			L.S.	342,000
	(2) Machinery			L.S.	109,000
	(3) Unwatering bulkheads			L.S.	267,000
	(4) Service bridge			L.S.	78,000
	(5) Electrical items			L.S.	138,000
	Gates and machinery				$ 934,000
e.	Operations building			L.S.	16,000
f.	Misc. items			L.S.	24,000
	TOTAL WESTERN PASSAGE LOCK				$ 6,943,000

APPENDIX II

Table 12

TIDAL POWER PROJECT

LITTLE LETITE PASSAGE LOCK

	Item	Quantity	Unit	Unit Price	Amount
a.	Cofferdams			L.S.	$ 212,000
b.	Excavation				
	(1) Rock				
	(a) In dry	57,400	cy	2.00	$ 115,000
	(b) Underwater	15,370	cy	15.00	231,000
	(c) Backfill	6,000	cy	.20	1,000
	(d) Fine rock grading	7,700	sy	2.25	17,000
		Excavation			$ 364,000
c.	Concrete				
	(1) Foundation preparation			L.S.	$ 6,000
	(2) Lock structure	14,150	cy	52.50	743,000
		Concrete			$ 749,000
d.	Gates and machinery				
	(1) Gates			L.S.	$ 116,000
	(2) Machinery			L.S.	89,000
	(3) Unwatering bulkheads			L.S.	56,000
	(4) Service bridge			L.S.	43,000
	(5) Electrical items			L.S.	103,000
		Gates and machinery			$ 407,000
e.	Operations building			L.S.	$ 16,000
f.	Misc. items			L.S.	$ 8,000
	TOTAL LITTLE LETITE PASSAGE LOCK				$1,756,000

APPENDIX II

Table 13

TIDAL POWER PROJECT

QUODDY ROADS LOCK

Item	Quantity	Unit	Unit Price	Amount
a. Cofferdams			L.S.	$1,231,000
b. Excavation				
(1) Rock				
(a) In dry	14,000	cy	4.00	$ 56,000
(b) Underwater	5,900	cy	25.00	148,000
(c) Backfill	5,200	cy	2.35	12,000
(d) Fine rock grading	4,200	sy	2.25	9,000
	Excavation			$ 225,000
c. Concrete				
(1) Foundation Preparation			L.S.	$ 7,000
(2) Lock structure	16,750	cy	51.00	854,000
	Concrete			$ 861,000
d. Gates and machinery				
(1) Gates			L.S.	$ 116,000
(2) Machinery			L.S.	89,000
(3) Unwatering bulkheads			L.S.	52,000
(4) Service bridge			L.S.	43,000
(5) Electrical items			L.S.	103,000
	Gates and machinery			$ 403,000
e. Operations building			L.S.	$ 16,000
f. Misc. items			L.S.	$ 10,000
	TOTAL QUODDY ROADS LOCK			$2,746,000

APPENDIX II

Table 14

TIDAL POWER PROJECT

Item	Quantity	Unit	Unit Price	Amount
DAMS				
a. Letite passages (3,740,000 c.y.)				$ 3,891,000
b. McMaster Is. to Deer Is. (1,241,000 c.y.)				2,531,000
c. Head Harbour Passage,East (20,311,000 c.y.)				21,098,000
d. Head Harbour Passage,West (7,203,000 c.y.)				9,591,000
e. Indian River (5,362,000 c.y.)				4,519,000
f. Western Passage (12,322,000 c.y.)				15,387,000
g. Carryingplace Cove (345,000 c.y.)				650,000
h. Quoddy Roads (2,750,000 c.y.)				5,997,000
TOTAL DAMS (53,274,000 c.y.)				$63,664,000

Table 15

TIDAL POWER PROJECT

LUBEC CHANNEL				
a. Excavation				
(1) By hydraulic dredge	345,000	cy	.90	$ 311,000
(2) By dipper dredge	170,000	cy	1.90	323,000
TOTAL LUBEC CHANNEL				$ 634,000

Table 16

TIDAL POWER PROJECT

FISHWAYS				
a. Powerplant - 500 mw		L.S.		$ 1,026,000
b. Head Harbour emptying gates		L.S.		272,000
TOTAL FISHWAYS				$ 1,298,000

APPENDIX II

Table 17

TIDAL POWER PROJECT

Item	Quantity	Unit	Unit Price	Amount
SERVICE FACILITIES (500 mw)				
a. Service roads				
(1) In United States			L.S.	$ 210,000
(2) In Canada			L.S.	522,000
	Service roads			$ 732,000
b. Buildings, grounds and facilities				
(1) Housing			L.S.	170,000
(2) Service buildings			L.S.	160,000
(3) Water supply			L.S.	87,000
(4) Roads and railroad sidings			L.S.	96,000
(5) Operating equipment			L.S.	625,000
	Buildings, grounds and facilities			$1,138,000
	TOTAL SERVICE FACILITIES			$1,870,000

APPENDIX II

Table 18

TIDAL POWER PROJECT

Item	Quantity	Unit	Unit Price	Amount
RELOCATIONS (500 mw)				
a. Relocations in United States				
(1) Roads and bridges				
(a) Highways			L.S.	$ 54,000
(b) Railroad			L.S.	212,000
(c) Highway and railroad bridge			L.S.	4,155,000
	Roads and bridges			$ 4,421,000
(2) Waterlines			L.S.	64,000
(3) Telephone and telegraph lines			L.S.	30,000
(4) Electric lines			L.S.	55,000
(5) Cemeteries			L.S.	2,000
(6) U.S. Coast Guard			L.S.	250,000
(7) International boundary monuments			L.S.	10,000
	Relocations in United States			$ 4,832,000
b. Relocations in Canada				
(1) Electric lines			L.S.	95,000
(2) Cemeteries			L.S.	4,000
	Relocations in Canada			$ 99,000
	TOTAL RELOCATIONS			$ 4,931,000

APPENDIX II

Table 19

TIDAL POWER PROJECT

LANDS AND DAMAGES (500 mw)

a. Lands and damages in United States			
	(1) Lands and improvements	LS	$ 486,000
	(2) Damages, modification of structures in low pool	LS	557,000
	Lands and damages in United States		$1,043,000
b. Lands and damages in Canada			
	(1) Lands and improvements	LS	$ 359,000
	(2) Modification of structures	LS	468,000
	Lands and damages in Canada		$ 827,000
	LANDS AND DAMAGES		$1,870,000

Table 20

ESTIMATE OF COST

DICKEY PROJECT - 190 MW

Item	Quantity	Unit	Unit Price	Amount
1. LANDS AND DAMAGES				
a. Lands (109,850 ac.)			L.S.	$ 3,400,000
b. Improvements (210 bldgs.)			L.S.	300,000
c. Severance			L.S.	700,000
d. Resettlements			L.S.	55,000
e. Water rights			L.S.	10,000
f. Access roads easements			L.S.	4,000
TOTAL LANDS AND DAMAGES				$ 4,469,000
2. RELOCATIONS				
a. Roads and Bridges			L.S.	$ 1,300,000
b. Power and telephone lines			L.S.	13,000
c. Cemeteries			L.S.	50,000
TOTAL RELOCATIONS				$ 1,363,000
3. RESERVOIR CLEARING			L.S.	$ 2,000,000
4. DAMS				
a. Stream control and diversion				
(1) Inlet				
(a) Earth excavation	1,020,000	c.y.	.50	$ 510,000
(b) Rock excavation	235,000	c.y.	1.80	423,000
(c) Gates, racks and guides	611,400	lbs.	.50	306,000
(d) Concrete	6,020	c.y.	55.00	331,000
Inlet				$ 1,570,000
(2) Gate Structure				
(a) Rock excavation-shaft	20,000	c.y.	20.00	$ 400,000
(b) Gates and hoists			L.S.	262,000
(c) Concrete	20,200	c.y.	66.00	1,327,000
(d) Crane and structure			L.S.	138,000
(e) Valves			L.S.	300,000
(f) Elevator			L.S.	80,000
Gate structure				$ 2,507,000

Table 20 (cont.)

ESTIMATE OF COST

DICKEY PROJECT - 190 MW

Item	Quantity	Unit	Unit Price	Amount
4. DAMS (continued)				
a. Stream control and diversion (cont.)				
(3) Tunnels				
(a) Rock excavation	186,000	c.y.	20.00	$ 3,720,000
(b) Concrete lining	66,800	c.y.	45.00	3,006,000
(c) Misc. items			L.S.	146,000
Tunnels				$ 6,872,000
(4) Outlet				
(a) Earth excavation	97,000	c.y.	.60	$ 58,000
(b) Rock excavation	325,000	c.y.	1.80	585,000
(c) Concrete	1,600	c.y.	47.00	75,000
(d) Misc. items			L.S.	6,000
Outlet				$ 724,000
(5) Cofferdams			L.S.	120,000
Stream control and diversion				$11,793,000
b. Embankment				
(1) Preparation of site			L.S.	$ 76,000
(2) Excavation				
(a) Stripping	1,825,000	c.y.	.50	$ 913,000
(b) Cutoff trench	984,000	c.y.	.60	590,000
(c) Foundation grouting			L.S.	50,000
Excavation				$ 1,553,000
(3) Fill				
(a) Impervious fill	8,065,000	c.y.	.78	$ 6,291,000
(b) Pervious fill				
1) From earth excav.	5,600,000	c.y.	.13	728,000
2) From rock excav.	11,000,000	c.y.	.20	2,200,000
3) From borrow	28,800,000	c.y.	.68	19,584,000
Pervious fill				$22,512,000
(4) Gravel bedding and slope protection	1,100,000	c.y.	1.25	1,375,000
(5) Rock slope protection				
(a) From excavation	685,000	c.y.	.40	274,000
(b) From borrow	218,000	c.y.	4.50	981,000
Rock slope protection				$ 1,255,000
(6) Roadway across dam			L.S.	216,000
(7) Drainage tunnel			L.S.	150,000
Embankment (55,468,000 c.y.)				$33,428,000

Table 20 (cont.)

ESTIMATE OF COST

DICKEY PROJECT - 190 MW

Item	Quantity	Unit	Unit Price	Amount
4. DAMS (continued)				
c. Saddle dams				
(1) Falls Brook (7,310,000 c.y.)				$ 4,900,000
(2) Hafey Brook (1,980,000 c.y.)				2,507,000
(3) Blue Brook (38,000 c.y.)				142,000
(4) Campbell Brook (44,000 c.y.)				44,000
(5) Cunliffe Brook(211,000 c.y.)				396,000
Saddle dams (9,583,000 c.y.)				$ 7,989,000
d. Spillway				
(1) Preparation of site			L.S.	$ 75,000
(2) Excavation				
(a) Earth	800,000	c.y.	.50	400,000
(b) Rock	4,500,000	c.y.	1.80	8,100,000
Excavation				$ 8,500,000
(3) Concrete	92,600	c.y.	45.00	4,167,000
(4) Misc. items			L.S.	103,000
Spillway				$12,845,000
e. Intake				
(1) Approach channel				
(a) Earth excavation	320,000	c.y.	.60	$ 192,000
(b) Rock excavation	375,000	c.y.	1.80	675,000
Approach channel				$ 867,000
(2) Intake structure				
(a) Rock excavation	69,500	c.y.	1.80	$ 125,000
(b) Gates and hoists			L.S.	680,000
(c) Concrete	61,000	c.y.	41.50	2,532,000
Intake structure				$ 3,337,000
(3) Misc. items				110,000
Intake				$ 4,314,000
f. Allagash channel				
(1) Stream control and diversion			L.S.	$ 50,000
(2) Earth excavation	4,000,000	c.y.	.60	2,400,000
(3) Slope protection			L.S.	100,000
Allagash channel				$ 2,550,000
TOTAL DAMS				$72,919,000

Table 20 (cont.)

ESTIMATE OF COST

DICKEY PROJECT - 190 MW

Item	Quantity	Unit	Unit Price	Amount
5. PENSTOCKS				
a. Excavation				
(1) Earth	42,500	c.y.	.60	$ 26,000
(2) Rock	107,000	c.y.	1.80	192,000
Excavation				$ 218,000
b. Steel conduits	6,450,000	lbs.	.32	$ 2,060,000
c. Expansion joints			L.S.	60,000
d. Anchors and supports				
(1) Concrete	15,150	c.y.	53.00	793,000
(2) Steel	715,000	lbs.	.40	286,000
Anchors and supports				$ 1,079,000
e. Station service conduits			L.S.	$ 142,000
f. Fill over penstocks	65,000	c.y.	1.00	65,000
TOTAL PENSTOCKS				$ 3,624,000
6. POWERPLANT				
a. Powerhouse			L.S.	$11,300,000
b. Turbine, generators, etc.			L.S.	8,636,000
c. Accessory electrical equipment			L.S.	870,000
d. Misc. powerplant equipment			L.S.	870,000
e. Power transformers			L.S.	1,100,000
f. Tailrace				
(1) Excavation				
(a) Earth	1,430,000	c.y.	.50	715,000
(b) Rock	2,800,000	c.y.	1.80	5,040,000
Tailrace				$ 5,755,000
TOTAL POWERPLANT				$28,531,000
7. SWITCHYARD				
a. Circuit breakers			L.S.	$ 478,000
b. Disconnecting switches			L.S.	148,000
c. Grading, structures, bus, etc.			L.S.	957,000
TOTAL SWITCHYARD				$ 1,583,000

Table 20 (cont.)

ESTIMATE OF COST

DICKEY PROJECT - 190 MW

Item	Quantity	Unit	Unit Price	Amount
8. ACCESS ROADS				
a. Access roads to dam and recreation area			L.S.	$ 270,000
b. Rebuild highway from St. Francis to Lincoln School			L.S.	240,000
c. Ferry ramps and access roads			L.S.	50,000
TOTAL ACCESS ROADS				$ 560,000
9. BUILDINGS, GROUNDS AND FACILITIES				
a. Housing			L.S.	$ 187,000
b. Service buildings			L.S.	122,000
c. Operating equipment			L.S.	89,000
d. Marine plant			L.S.	122,000
e. Logway			L.S.	208,000
TOTAL BUILDINGS, GROUNDS AND FACILITIES				$ 728,000
SUBTOTAL DICKEY PROJECT				$115,777,000
Contingencies				16,935,000
SUBTOTAL				$132,712,000
Engineering, design, supervision and administration				14,954,000
TOTAL PROJECT FIRST COST (190 mw)				$147,666,000

APPENDIX II

Table 21

ESTIMATE OF COST

DICKEY PROJECT - 380 MW

Lands & Damages		$ 4,469,000
Relocations		1,363,000
Reservoir Clearing		2,000,000
Dams		72,919,000
Penstocks		7,249,000
Powerplant		
Powerhouse	$ 12,200,000	
Turbines & Generators	17,150,000	
Acc. Elect. Equip.	1,420,000	
Misc. Powerplant Equip.	990,000	
Power Transformers	1,578,000	
Tailrace	5,755,000	
Total Powerplant		39,093,000
Switchyard		1,940,000
Access Roads & Bridge		560,000
Buildings, Grounds & Facilities		728,000
SUBTOTAL		$130,321,000
Contingencies		18,691,000
SUBTOTAL		$149,012,000
Engineering, design, supervision & administration		16,559,000
TOTAL PROJECT FIRST COST (380 mw)		$165,571,000

APPENDIX II

Table 22

ESTIMATE OF COST

DICKEY PROJECT - 475 MW

Lands & Damages		$ 4,469,000
Relocations		1,363,000
Reservoir Clearing		2,000,000
Dams		72,919,000
Penstocks		9,062,000
Powerplant		
Powerhouse	$ 12,600,000	
Turbines & Generators	21,440,000	
Acc. Elect. Equip.	1,695,000	
Misc. Powerplant Equip.	1,045,000	
Power Transformers	2,056,000	
Tailrace	5,755,000	
Total Powerplant		44,591,000
Switchyard		2,787,000
Access Roads & Bridges		560,000
Buildings, Grounds & Facilities		728,000
SUBTOTAL		$138,479,000
Contingencies		19,700,000
SUBTOTAL		$158,179,000
Engineering, design, supervision & administration		17,476,000
TOTAL PROJECT FIRST COST (475 mw)		$175,655,000

APPENDIX II

Table 23

ESTIMATE OF COST

DICKEY PROJECT - 760 MW

Lands & Damages		$ 4,469,000
Relocations		1,363,000
Reservoir Clearing		2,000,000
Dams		72,919,000
Penstocks		14,503,000
Powerplant		
Powerhouse	$ 13,900,000	
Turbines & Generators	34,300,000	
Acc. Elect. Equip.	2,520,000	
Misc. Powerplant Equip.	1,220,000	
Power Transformers	2,534,000	
Tailrace	5,755,000	
Total Powerplant		60,229,000
Switchyard		3,466,000
Access Roads & Bridges		560,000
Buildings, Grounds & Facilities		728,000
SUBTOTAL		$160,237,000
Contingencies		22,321,000
SUBTOTAL		$182,558,000
Engineering, design, supervision & administration		19,880,000
TOTAL PROJECT FIRST COST (760 mw)		$202,438,000

APPENDIX II

Table 24

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Quantity	Unit	Unit Price	Amount
1. LANDS AND DAMAGES				
a. Lands (2150 ac.)			L.S.	$ 190,000
b. Improvements (60 bldgs.)			L.S.	180,000
c. Resettlements			L.S.	30,000
TOTAL LANDS AND DAMAGES				$ 400,000
2. RELOCATIONS				
a. Roads and bridges			L.S.	$ 1,200,000
b. Power and telephone lines			L.S.	38,000
TOTAL RELOCATIONS				$ 1,238,000
3. RESERVOIR CLEARING			L.S.	$ 40,000
4. DAMS				
a. Stream control and diversion			L.S.	$ 100,000
b. Embankment				
(1) Preparation of site			L.S.	$ 10,000
(2) Excavation				
(a) Stripping	200,000	c.y.	.50	100,000
(b) Cutoff trench	50,000	c.y.	.60	30,000
(3) Fill				
(a) Impervious fill	485,000	c.y.	.35	170,000
(b) Random fill	680,000	c.y.	.35	238,000
(c) Rock fill	97,000	c.y.	.40	39,000
(4) Gravel bedding	28,000	c.y.	1.50	42,000
(5) Rock slope protection				
(a) From excavation	64,000	c.y.	.40	26,000
(b) From borrow	19,000	c.y.	4.50	86,000
(6) Roadway across dam			L.S.	24,000
Embankment (1,373,000 c.y.)				$ 765,000

Table 24 (cont.)

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Quantity	Unit	Unit Price	Amount
4. DAMS (continued)				
c. Spillway.				
(1) Preparation of site			L.S.	$ 10,000
(2) Excavation				
(a) Earth	954,000	c.y.	.50	477,000
(b) Rock	282,000	c.y.	1.80	508,000
(3) Concrete	42,500	c.y.	45.00	1,913,000
(4) Taintor gates (4-40'x 30'), guides and Hoists			L.S.	400,000
(5) Miscellaneous items			L.S.	150,000
Spillway				$ 3,458,000
TOTAL DAMS				$ 4,323,000
5. POWERPLANT				
a. Powerhouse			L.S.	$ 1,650,000
b. Turbines, generators, etc.			L.S.	3,273,000
c. Accessory electrical equipment			L.S.	522,000
d. Misc. powerplant equipment			L.S.	261,000
e. Transformers			L.S.	126,000
f. Forebay and tailrace excavation				
(1) Earth	348,000	c.y.	.50	174,000
(2) Rock	158,000	c.y.	1.80	284,000
TOTAL POWERPLANT				$ 6,290,000
6. SWITCHYARD				
a. Circuit breakers			L.S.	$ 104,000
b. Disconnect switches			L.S.	43,000
Grading, structures, bus, etc.			L.S.	240,000
TOTAL SWITCHYARD				$ 387,000

Table 24 (cont.)

ESTIMATE OF COST

LINCOLN SCHOOL PROJECT

Item	Quantity	Unit	Unit Price	Amount
7. BUILDINGS, GROUNDS & FACILITIES			L.S.	$ 208,000
8. ACCESS ROADS			L.S.	$ 50,000
SUB-TOTAL				$12,936,000
Contingencies				1,776,000
SUB-TOTAL				$14,712,000
Engineering, design, supervision & administration				1,553,000
TOTAL PROJECT FIRST COST				$16,265,000